Evaluation of international risk assessment protocols for exotic species

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Summary

Exotic or non-native species are species which are introduced outside their natural past or present distribution by human mediated ways. They have shown to be potentially problematic, especially when they become invasive (i.e., species which have an extremely high rate of spread and whose introduction does or is likely to cause economic or ecological harm or harm to human health). This study entails a comparison of the effectiveness and utility of existing risk assessment protocols for exotic species in order to give useful recommendations for a successful and appropriate risk assessment tool for the Netherlands. The risk assessment protocols included in this study are (trans)nationally developed procedures from Australia, Belgium, Germany/Austria, Ireland, Norway, Switzerland, United Kingdom (UK) and United States/Canada/Mexico. Evaluation criteria for comparison of these protocols were related to risk assessment components, impact categories, data requirements, scoring methods, uncertainties, policy compliance, user friendliness and assessment time of the protocols (Appendix 1). Overall, two different approaches for risk characterization could be distinguished: (1) qualitative listing methods using formalized questions to assign high-risk species to a Black List, and (2) (quantitative) scoring methods, using the sum of the scores for various evaluation criteria as indicator for a high, medium or low risk. The scope of the protocols ranges from ecological impact only to inclusion of ecological, economical, human health and social effects.

A strength weakness analysis (based on the evaluation results) put forward the UK Risk Assessment Scheme as the most complete one, but also the most data and labour intensive protocol. The German-Austrian protocol (GABLIS) and secondly the Swiss classification key, although both limited in scope, were regarded as robust risk assessment methods for a rapid screening based on their uncertainty and impact approach. Both protocols apply a listing approach, assigning species to a Black list. Further analysis of impact definitions and endpoints for ecological, economical and human health effects revealed vaguely defined impact definitions with little explanation or quantification as to what actually qualifies a significant (harmful) effect.

Comparison of national risk outcomes of the protocols for the same species gives a similar risk classification for 64% of the species. A number of protocols have been used by several countries and a comparison of the scores for similar species also indicated differences in risk classifications. Different risk classifications may occur due to differences in species-climate or species-environment match in various countries or biogeographical regions, in data availability, and experience and number of risk assessors. In a national context the use of different risk assessment procedures may yield differences as well. From practical experience of the protocols we learned that small changes in the assessment can lead to different risk outcomes, in particular when the risk assessment protocol uses cut-off thresholds to determine the final risk classification.

Based on the results of this study we recommend developing a multiple stage risk assessment approach for risk classification of exotic species in the Netherlands. As a quick, generic risk assessment for screening of risks posed by potentially arriving and established exotic species we recommend to use a qualitative listing approach based on the German-Austrian protocol (GABLIS) and Swiss protocol as a screening tool for high risk (Black List) species. For use of GABLIS as the Dutch standard risk procedure three major adjustments have to be made: (1) to include economic, human health and safety effects, (2) to develop specific criteria for assessing risk to areas, habitat types, species (populations) that are protected by European nature and water Directives and (3) to give a clear definition of the biological-ecological criteria which are used to distinguish between the Grey observation list and White list. A second, ready to use

option for a quick, generic approach would be to adapt the Swiss protocol to suite all taxonomic groups and to apply to Dutch standards regarding the possibility of ecological effects in human-mediated areas. In the second step, high risk species are subject to a detailed risk assessment (e.g., pathways, impacts and uncertainties). An example of a comprehensive detailed assessment is the UK Risk Assessment Scheme. In risk assessment special attention should be paid to definition of (significant) impact levels to ensure consistency between risk assessments and assessors. Further recommendations are to make use of a separate Climate list and finally to ensure an independent review process.

1 Introduction

Exotic (or alien or non-native) species may cause ecological, economical or human health effects, especially in the case when they become invasive. Management of invasive alien species is difficult for a number of reasons. First of all, it is difficult to predict which (introduced) species are able to establish viable populations and spread and for which entry should be prevented. Secondly, impacts of potentially invasive alien species are not always known and they may differ for various ecosystems and regions. Therefore, it is not always clear whether measures are needed. Finally, eradication and control measures for invasive species are costly and do not prevent new species from entering. This explains the need for sound risk assessments to screen introduced and potential incoming species, and to predict whether these species will become invasive.

As an important trade nation, the Netherlands is facing problems with invasive alien species. Parties of the Convention on Biological Diversity (CBD), including the Netherlands, have ranked invasive exotic species as the largest threat to biodiversity after loss of habitat and exploitation (CBD 1992). The CBD parties agreed that Member States have to develop policy 'to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species' (article 8h). The Convention was followed by guiding principles on invasive species (CBD 2004) and in the same year the European Strategy for Invasive Alien Species (Genovesi and Shine 2004) stressed the importance of risk assessment in exotic species policy in a European context. The latter proposes the use of a listing system to assign species to a black, white or grey list, depending on the severity of impact and data availability.

The Dutch government has issued a policy memorandum aimed at prevention, control and management of negative impacts of exotic species (Ministry of Agriculture, Nature and Food Quality 2007). The need for a coordinating authority for invasive exotic species (COIE) was spoken out, which in 2009 resulted in the foundation of Invasive Alien Species Team (TIE). The task of TIE is to advise the Minister of Agriculture Nature and Food Quality on the approach to be taken concerning invasive exotic species. Among other responsibilities TIE has been commissioned to carry out risk analyses for exotic species and to make recommendations on the necessity of prevention, control or available options for management of exotic species (Ministry of Agriculture, Nature and Food Quality 2007).

A number of (European) governments and research institutes have recently developed risk assessment protocols for exotic species in order to predict their invasiveness. The Netherlands intends to implement a standard procedure for risk assessment of exotic species. A comparison of the effectiveness and utility of existing risk assessment protocols can give useful indications for a successful and appropriate risk assessment tool for the Netherlands. Either one of (or elements from) the existing protocols may proof to be an appropriate tool. Therefore, TIE recently commissioned to Radboud University Nijmegen a research project to evaluate existing risk assessment protocols. The aim of this project is:

- To compare and analyze the strengths and weaknesses of existing risk assessment protocols in predicting the risks associated with the introduction, establishment, spread and impact of non-native species in a Dutch context.
- To examine the risk assessment protocols by means of a case study and report on their usefulness and user experiences.
- To draw up recommendations for a standard risk assessment protocol for non-native species and to distinguish the most appropriate approach for Dutch risk assessment of non-native species.

The aim as described above does not include development of a risk assessment protocol for exotic species, but is primarily focused on formulating recommendations for a risk assessment protocol based on the comparison and analysis of existing protocols.
This report presents the final results of the project. Chapter 2 briefly describes the materials and methods used in this study. Chapter 3 gives the results, including (1) a description of the risk assessment protocols, (2) an evaluation and comparison of the protocols, using a formalized set of criteria, (3) an analyses of applied methods for impact assessment (4) a strength-weakness analyses of the protocols, and (5) a comparison of risk assessment classifications. In chapter 4 recommendations for the development of a Dutch protocol will be outlined. Finally, chapter 5 presents our conclusions and recommendations.

2 Materials and methods

The recommendations for development of a Dutch procedure for risk assessment of exotic species are based on three pillars: (1) an evaluation of risk assessment protocols, including a strength-weakness analysis, (2) an analyses of the characterization of impact assessment or effect classification, and (3) a comparison of available risk scores and results of protocol testing. In total eight protocols for risk assessment of exotic species were evaluated. According to the project tender, the current study should include the protocols of Australia, Belgium, Germany/Austria and United Kingdom. Based on an internet search for contemporary risk assessment procedures, four protocols were added to this selection (i.e., Ireland, Norway, Switzerland and United States/Canada/Mexico).

2.1 Data acquisition and literature search

Information on the recently developed German-Austrian protocol was acquired via the authors (F. Essl, personal communication 1 February 2010). All other protocols and background documents were obtained via internet. An additional literature search was conducted for the use of protocols and the outcomes of risk assessments of exotic species in various countries (e.g., risk scores of species). These data offered possibilities to evaluate the effects of different methodologies, national settings and assessors on risk classifications of exotic species.

2.2 Evaluation risk assessment protocols

This study evaluates the risk assessment protocols as well as available background documentation, such as supporting information, guidelines, MS Access applications, reviews and scientific articles. The protocols were described, briefly summarized (Table 3.1) and subsequently analyzed using a set of evaluation criteria (Appendix 1). The evaluation criteria were developed in cooperation with TIE and they relate to risk assessment components, impact categories, data requirements, scoring methods, uncertainties, compliance to national policy and EU directives (i.e., Habitat/Bird Directive and Water Framework Directive), user friendliness and assessment time of the protocols. Several criteria were specified by means of sub-criteria. The main criteria were developed independently and can therefore only be compared between countries. Sub-criteria can be compared to the other sub-criteria in the same category and between countries. The protocols were scored using a four-point scale from 0-3 (i.e., -, ±, +, ++) indicating whether this criterion was not, partly, fairly or extensively elaborated. From the results of the evaluation, the strengths and weaknesses of each protocol were deduced.

2.3 Analysis of effect assessment criteria

While analysing the protocols, special emphasis was laid on the assessment and definition of actual (ecological) effects resulting from the introduction of exotic species. All parts of the protocols related to impact assessment were examined and summarized, unravelling not only the scope of the impact assessment but also the effect definition and characteristics. In other words, according to the protocol, what qualifies a detrimental ecological, economic, or health effect?

2.4 Comparison of risk assessment end scores

The consistency of risk scores for exotic species was analyzed by comparing risk assessment outcomes in three ways. First of all, national (original) risk assessment end scores were screened for similar species and they gave a comparison of risk outcomes using different protocols in different contexts (or countries). Secondly, available risk classifications for exotic species resulting from the use of the same protocol in different contexts (or countries) were compared. Thirdly, a comparison was made between risk classifications for exotic species from different risk assessment protocols applied in one country. Finally, the selected protocols were tested by performing risk assessments for two species (i.e., the Indian house crow (*Corvus splendens*) and the Ponto-Caspian round goby (*Neogobius melanostomus*)) in a Dutch context. The risk assessments were carried out as prescribed in the guidelines using Dutch input data when asked for climate or site-specific data and based on literature collected in recent Dutch evaluation reports (Spikmans et al. 2010, Slaterus et al. 2009). This final comparison rules out any inconsistencies which may occur due to differences in climate (between countries) and assessors.

3 Results

First, a description of international risks assessment protocols is given (paragraph 3.1). In paragraph 3.2 the results of the comparison of risk assessment protocols are presented. Paragraph 3.3 deals with the characterization of effect valuation. Paragraph 3.4 gives the results of the strength and weakness analysis of the protocols. Finally, the results of the testing and evaluation of outcomes of the risk assessment protocols are presented in the last paragraph.

3.1 Description of international risks assessment protocols

This paragraph briefly describes the eight selected risk assessment protocols, including protocols from Belgium, United Kingdom, Germany/Austria, Ireland, Norway, Switzerland, Australia and United States/Canada/Mexico. The basic features of these protocols are presented in table 3.1.

3.1.1 Member States of the European Union

Belgium - ISEIA

The Belgian Biodiversity Platform facilitates the Invasive Species Environmental Impact Assessment (ISEIA) protocol. Risk assessments are available online in the Harmonium Information System which now includes scores for 90 species. The protocol assesses environmental impact only and can be applied to all species. The assessment consists of four sections matching the last steps of the invasion process: the potential for spread (1) and establishment (2) and adverse impacts on native species (3) and ecosystems (4). Scores for each section are based on organism's history of impact in neighbour areas and their ecological profiles. Species are assigned to risk category: A - Black list (high environmental risk), B - Watch list (moderate environmental risk) or C (no threat). In addition, there is also an Alert list for species that are not yet present but are invasive in neighbouring areas (Branquart 2007).

Germany and Austria - GABLIS

The German-Austrian Black List Information System (GABLIS) is a recently developed, transnational risk assessment tool for invasive alien species in Germany and Austria. Although data on economical and health effects is included as additional information, GABLIS only assesses ecological effects and does not incorporate economic or health problems in the classification key. The system has been tested for vascular plants and fish, but has been designed to conduct risk assessments for species of all taxonomic groups. Based on five basic and six complementary, biological-ecological criteria species are assigned to the White, Grey or Black list, according to their potential risk: alien species with scientifically sound evidence of a significant threat on native biodiversity are assigned to the Black List. Alien species with a less evidence-based reliability of effects are assigned to the Grey List and alien species which do not pose a threat to native biodiversity are assigned to the White List. The Black List is further divided into three sub-lists, the so-called warning, action and management list. These lists are based on the distribution of the species and the feasibility of eradication measures. The Grey List is further divided into an observation list and an operation list. This subdivision is based on the level of certainty of the assessment (Essl et al. 2010).

United Kingdom - Risk Assessment Scheme

In response to a key recommendation from the Review of Non-Native Species Policy in 2003, the UK Risk Assessment Scheme for all Non-native Species (Baker 2005, 2008) has been

developed. The Non-Native Species Secretariat (NNSS) on behalf of The Department for Environment, Food and Rural Affairs (UK), the Scottish Government and the Welsh Assembly Government manages the risk analysis process. The scheme can be used for all taxonomic groups and roughly consists of two parts: (1) a preliminary assessment (14 questions) to determine whether a detailed risk assessment is needed, and (2) a detailed risk assessment scheme (51 questions) to assess the potential for entry and establishment, the capacity for spread and the extent to which economic, environmental or social and human health impacts may occur. Six additional modules provide methods for identifying invasive attributes, evaluating pathways of introduction, determining the vulnerability of receptors, quantifying economic impacts, summarizing risks and uncertainties and selecting risk management options. The final risk score is aggregated to a high, medium or low risk. The risk assessment is available as a template using a computer program (EPPO 2010). Specific invasive attribute spreadsheets for freshwater fish (FISK), marine fish and invertebrates (MFISK and MI-ISK), freshwater invertebrates (FI-ISK) and amphibians (AmphISK) are available online (Cefas 2010). In the report we will refer to the complete UK Risk Assessment Scheme, unless we explicitly name a specific part (e.g., FISK).

Ireland - Invasive Species Ireland Risk Assessment

In 2006 the Northern Ireland Environment Agency and the National Parks and Wildlife Service started the Invasive Species Ireland project. The risk assessment system developed within this project has been designed for all species. It has incorporated a number of questions from the UK Risk Assessment Scheme and similarly has a preliminary and detailed assessment. The risk assessment is based on questions relating to the invasion history, vectors and pathways, suitability of habitats, propagule pressure, establishment success, spread potential and assesses ecological, economic and impacts on human and animal health. There are separate assessment formats for potential and established invasive species. Finally, the species are assigned to the high, medium or low risk category based on their summed scores (Invasive Species Ireland 2008). The risk assessment will be reviewed in the autumn of 2010. In addition, a pathway risk assessment and a detailed risk assessment to inform a "ban for sale" of invasive species are currently being developed (J. Kelly, personal communication 24 March 2010).

3.1.2 Other European countries

Norway – 2007 Norwegian Black List

The Norwegian Biodiversity Information Centre has initiated ecological risk analysis of alien species which resulted in the 2007 Norwegian Black List. The risk assessment procedure can be applied for all species but only assesses ecological effects. It is a two-phase assessment with a simplified risk analysis where species that have been documented as being problem-free are categorized as having low risk. For most of the species, there is no documentation that they are problem-free and a risk analysis must then be performed in the second phase. Then, species are categorized as species which most probably have no, or no significant, negative impact on indigenous biological diversity (low risk), species about which too little is known to assess whether they have negative impacts (unknown risk) or species that have negative impacts on indigenous biological diversity (high risk) (Gederaas et al. 2007). Recently, the Department of Biology of the Norwegian University of Science and Technology in Trondheim has finalized a report that provides new quantitative methods for blacklisting of Norwegian invasive alien species (Sæther et al. 2010). The reasoning for developing a new quantitative risk assessment was the unsatisfactory performance and transparency of the qualitative methods that formed the basis for the 2007 Black List (T. Holmern, personal communication 5 March 2010). In this new method species are classified according to their potential rate of spread into new environments and according to their potential impact on other species and on the structure of critical landscape

types. Due to time restrictions, it was not possible to incorporate the latest publication in this report.

Switzerland - Classification key for neophytes
The Swiss Commission for Wild Plant Conservation (CPS/SKEW) was asked by the Swiss Federal Office for Environment to develop a classification key for invasive alien plant species (in German: Bestimmungsschlüssel zur Einteilung von Neophyten in der Schweiz in die Schwarze Liste und Watch-Liste). In 2005 the working group published their results in a German journal (Weber et al. 2005). The risk assessment protocol is only applicable to plants and it assesses damage to biodiversity, human health and economy using a total of ten questions. Species are then assigned to a Black or Watch List. The Black List includes plants that actually cause damage and the establishment and spread of these species must be prevented. The Watch List includes plants that have the potential to cause damage or are already causing damage in neighbouring countries. The spread of these pants needs to be monitored and if necessary prevented.

3.1.3 Other continents

Australia and New Zealand - Risk Assessment Models for Establishment of Exotic Vertebrates
The report on risk assessment models for establishment of exotic vertebrates in Australia and New Zealand brings together reviews and models from previous reports commissioned by the Vertebrate Pest Committee (VPC) and the Australian Government. The Invasive Animals Cooperative Research Centre is the coordinating institute for invasive species research and recently published this extensive report on risk assessment (Bomford 2008). The report describes risk assessment models for exotic vertebrate species, including models for mammals and birds, reptiles and amphibians and one for freshwater fish. The most elaborate model (mammals and birds) takes into account risk (or likelihood) of establishment and potential economic, environmental and societal (including human health) impacts. The establishment risk, pest risk and escape risk are aggregated into a VPC threat category, ranging from low, moderate, high to extreme risk. For reptiles, amphibians and fish only establishment risk is assessed. Australia has a history in application of risk assessments to prevent pests. In 1999 the Australian government already developed a Weed Risk Assessment (WRA) to assess weed potential of proposed new plant imports (Pheloung et al. 1999), which is still in use by Biosecurity Australia. This unit of the Biosecurity Services of the national government also performs Import Risk Assessments (IRAs) to identify and classify potential quarantine risks and to develop policies to manage them.

United States, Canada and Mexico - Trinational Risk Assessment Guidelines
The trinational risk assessment guidelines for aquatic alien invasive species have been initiated by the federal authorities of the three nations. Together they form a partnership in the Commission for Environmental Cooperation (CEC) for North America which published the guidelines. The objective of the guidelines is to provide a standardized process for evaluating the risk to biodiversity of introducing aquatic non-indigenous organisms into a new environment (CEC 2009). Species are selected for risk assessment with a screening tool and if there is reason for concern an Organism Risk Assessment is carried out. This model is divided in two major components: the probability of establishment and the consequence of establishment and covers ecological, economic and social and cultural impacts. The final organism risk potential is rated as low (acceptable risk; no concern), medium (unacceptable risk; moderate concern) or high (unacceptable; major concern). These guidelines are an updated version of the review process developed by the Aquatic Nuisance Species Task Force (ANSTF) in the United States (ANSTF 1996).

Table 3.1 Characteristics of risk assessment protocols.

	EU member states			
Country	**Belgium**	**United Kingdom**	**Germany/Austria**	**Ireland**
Name	Invasive Species Environmental Impact Assessment (ISEIA) protocol	The UK Risk Assessment Scheme for all Non-Native Species	The German-Austrian Black List Information System (GABLIS)	Invasive Species Ireland Risk Assessment
Year	2007	2005	2010	2006
Instrument	Harmonia Information System	NAPRA (MS Access Application)	-	Invasive Species database (MS Access Application)
Legal status	advisory tool	advisory tool	recommendary	advisory tool
Responsible authority	Belgian Science Policy Office	UK Department of Environment, Food and Rural Affairs, The Scottish Government and Welsh Assembly Government	Environment Agency Austria and German Federal Agency for Nature Conservation	Northern Ireland Environment Agency and the National Parks and Wildlife Service
Set up by	Belgian Biodiversity Platform	UK Department of Environment, Food and Rural Affairs	German Federal Agency for Nature Conservation	Northern Ireland Environment Agency and the National Parks and Wildlife Service
Execution risk assessment	Belgian scientists	an expert in taxon or pathway	group of experts, i.e. the authors of manuscript GABLIS	Invasive Species Ireland Project
(Peer) review of results	scientific committee	one expert peer reviewer and review by panel of RA experts	-	-
Application	90 species assessed (vascular plants and vertebrates)	20 assessments completed and 62 in progress	tested on 74 vascular plants and 61 fish	over 500 preliminary and 54 detailed assessments done
Evaluation	-	Booy et al (2006)	-	self evaluation project (2008)
Taxon specific	generic	generic	generic	generic
Online database available	yes	yes	no	yes
Approach	listing system; Alert, Black and Watch List	threat categories: high, medium or low	listing system; White, Grey and Black List	scorecard approach: high, medium or low risk
Scope	ecological impact	ecological, economic and social (human health) impacts	ecological impact	ecological, economic and human health impacts
Reference	Branquart (2007)	EPPO (2010); Baker et al. (2008)	Essl et al. (2010)	Invasive Species Ireland (2008)
Adapted procedure	EPPO pest risk assessment scheme	EPPO pest risk assessment scheme, WRA	-	Questions from UK Assessment Scheme included
Note	scientific publication in prep.	preliminary assessment and detailed assessment	not yet published; results Germany and Austria compared	preliminary assessment and detailed assessment
Available documents	guidelines	guidelines, program and article	manuscript (in prep.)	program and protocol
Website	http://ias.biodiversity.be/ias/definitions	https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm	not available	http://www.invasivespeciesireland.com/downloads/risk_assessment.asp

Table 3.1 continued.

	Other European countries		Non European countries	
Country	**Norway**	**Switzerland**	**Australia/New Zealand**	**US/Canada/Mexico**
Name	2007 Norwegian Black List	Classification Key for Neophytes	Risk assessment models for establishment of exotic vertebrates in AU and NZ	Trinational Risk Assessment Guidelines for Aquatic Alien Invasive Species
Year	2007	2005	2008	2009
Instrument	Alien Species Database	-	-	-
Legal status	advisory tool		endorsed tool	advisory tool
Responsible authority	Ministry of Research and Education	Swiss Federal Office for Environment (FOEN)	Australian Government Department of the Environment, Water, Heritage and the Arts; The Bureau of Rural Sciences	state and federal governments
Set up by	The Norwegian Biodiversity Information Centre	The Swiss Commission for Wild Plant Conservation (CPS/SKEW)	Invasive Animals Cooperative Research Centre	partnership of national federal authorities (joined in Commission for Env. Cooperation
Execution risk assessment	team of experts composed of scientists from six research institutions	experts from Swiss Commission for Wild Plant Conservation	Western Australia Department of Agriculture & Food (DAFWA)	national experts and the Trinational Alien Invasive Species Working Group
(Peer) review of results	-	-	independent or specialist reviewer	independent reviewer
Application	217 species assessed	44 species on Black and Watch List	tested on 40 exotic animals, including birds, mammals, reptiles and amphibians	tested on 2 fish species; now applied in each country
Evaluation	revised protocol March 2010	-	Massam et al. (2010)	Leung and Dudgeon (2008)
Taxon specific	generic	plant species	vertebrates	aquatic species
Online database available	yes	yes	in preparation	no
Approach	risk categories: low, unknown and high risk	listing system; Black and Watch List	threat categories: low, moderate, serious or extreme	scorecard approach: high, medium or low risk potential
Scope	ecological impact	ecological, economic and human health impacts	ecological, economic and social (human health) impacts	ecological, economic and social/cultural impacts
Reference	Gederaas et al. (2007)	Weber et al. (2005)	Bomford (2008)	CEC (2009)
Adapted procedure	-	-	Bomford (2003) and (2005); Bomford and Glover (2004)	Review Process of ANSTF
Note	preliminary assessment and detailed assessment	classification key in German	different models for each taxonomic group	trinational guidelines
Available documents	report	published article	report	report
Website	http://www.artsdatabanken.no/Article.aspx?m=180&amid=2835	http://www.cps-skew.ch/english/info_invasive_plants.htm	http://www.feral.org.au/content/policy/risk_assess_list.cfm http://www.invasiveanimals.com	http://www.cec.org/Storage/62/5516_07-64-CEC%20invasives%20risk%20guideli

3.2 Comparison of risk assessment protocols

This chapter describes the evaluation of international risk assessment protocols using a set of formalized criteria. These criteria address the following themes: scope and completeness, data requirements, scoring methods, uncertainties, policy compliance, user friendliness and time needed to complete the risk assessment. The applied evaluation criteria are presented in Appendix 1. The Norwegian protocol for determining Black List species has been revised, but a draft of the novel assessment scheme is not yet available. Therefore, the Norwegian risk assessment procedure is excluded from detailed evaluation.

3.2.1 Scope and completeness

The available risk assessment protocols remarkably differ regarding their scope and completeness (Table 3.2). The majority of the protocols are generic and they can be applied to all taxonomic groups and types of ecosystems. Exceptions are the Swiss (only plants), Australian (only vertebrates) and trinational Northern American (only aquatic species) protocols. Due to detailed taxon related questions, the Australian protocol is a true example of a taxon-specific protocol. The other two protocols have a broader base and may easily be adapted to assess risks of other taxa as well. Only few protocols explicitly focus risk assessments on the entire life cycle of exotic species. All protocols more or less include the same components in the risk assessment (i.e., introduction, establishment, spread, impact and management). However, the introduction stage is often less elaborated than other stages, or even missing in protocols of two countries (i.e., Belgium and Switzerland). The latter is probably related to the fact that in these countries the introduction phase of species is already anticipated in their species selection (species introduction is used as a criterion for conducting the risk assessment). Based on the scope of impact categories, a distinction can be made between protocols assessing ecological effects only (i.e., the Belgian ISEIA and German-Austrian GABLIS protocol) and the remaining ones with more comprehensive impact assessments (including ecological, economical and social or human health impacts). Safety is included in four of the seven protocols but criteria for risks in this category vary greatly between countries. They refer to harm to property or buildings, harm to people (i.e., aggressive behaviour of animals) or are not specified at all.

Table 3.2 Comparison of completeness of risk assessment protocols.

Scope and completeness	**BE**	**DE/AT**	**UK**	**IE**	**CH**	**AU/NZ**	**US/CA/MX**
General							
Taxonomic scope	++	++	++	++	-	±	-
Ecosystem scope	++	++	++	++	++	++	-
Life cycle	-	-	++	±	-	-	+
Risk assessment components #	4	5	5	5	4	4	5
Introduction	-	±	++	+	-	±	+
Establishment	+	+	++	++	±	+	+
Spread	±	±	++	++	±	+	+
Impact	±	+	+	+	±	±	+
Management	±	±	++	+	±	-	±
Impact categories #	2	2	5	4	5	5	5
Biodiversity	++	++	+	+	±	++	+
Ecosystem functioning	++	++	+	±	+	+	++
Economy	-	-	++	+	±	±	++
Human health	-	-	±	+	±	+	+
Safety	-	-	+	-	+	++	±

-, ±, +, and ++: not, partly, fairly and extensively elaborated, respectively; #: number of categories or components included.

3.2.2 Data requirements

The degree of scientific underpinning of risk assessment protocols is divided in three sub-criteria: (1) reference in the protocol to a supporting knowledge framework for species spread and spatial distribution data, (2) the requirements for referring to data sources, and (3) whether an explicit demand for peer-reviewed references is stated (Table 3.3). The other four criteria deal with the inclusion of spatial or site-specific data (e.g., areas susceptible to invasion), temporal changes (e.g., effects of climate change on establishment, temporal changes in effects of exotic species and expected policy changes), level of expertise, and feasibility. The latter is assessed by comparing how is dealt with knowledge gaps and outcomes of previous risk assessments. A positive judgment on these two sub-criteria will increase the feasibility regarding data availability.

Although the scientific base and data requirements strongly differ (Table 3.3), all risk assessment protocols require spatial data to predict establishment and spread of exotic species. Climate change or other temporal changes over time are included explicitly by only three risk assessment procedures (i.e., the German-Austrian, UK and Irish schemes). To avoid data scarcity protocols do not restrict data input by explicit data quality demands. Besides peer-reviewed literature also grey literature, (online) databases and expert judgment are allowed to underpin assessments. The latter is considered an important element of the risk assessment, which is reflected in the level of expertise needed to complete the risk assessment. Finally, the outcome of previous risk assessments (abroad) is regarded as relevant data by the majority of the reviewed protocols.

Table 3.3 Comparison of data requirements of risk assessment protocols.

Data requirements	**BE**	**DE/AT**	**UK**	**IE**	**CH**	**AU/NZ**	**US/CA/MX**
Degree of scientific base							
Supporting knowledge framework	-	-	±	-	-	-	-
Documentation references	±	+	++	±	-	-	++
Demand high quality references	-	+	-	±	-	±	+
Spatial data	±	+	+	+	+	++	+
Temporal data	-	+	++	+	-	±	±
Level of expertise	±	++	++	++	++	++	++
Feasibility							
Knowledge gaps	±	+	++	+	±	++	++
Inclusion previous risk assessments	-	-	++	++	++	+	+

-, ±, +, and ++: not, partly, fairly and extensively elaborated, respectively.

3.2.3 Scoring methods

Scoring methods were evaluated using eight criteria (Table 3.4). First of all, the protocols were checked on application of a preliminary screening before conducting a detailed risk assessment. Next, the robustness of the method is evaluated by examination of either risk components (i.e., likelihood and magnitude of establishment or impact of exotic species), checking whether the protocol has been tested or uses components of already existing risk assessment procedures and evaluating the relevance of values represented by the assessment criteria or questions. The following criteria refer to possible quantitative elements, weighting procedures and aggregation methods used in the procedure. Finally, the comparability of the end scores, including ranking possibility and clarity of the end scores for indicating invasiveness, and potential additional output is analysed.

Overall, two different approaches for risk characterization can be distinguished: (1) qualitative listing methods using formalized questions to assign high-risk species to a Black List, and (2) (quantitative) scoring methods, using the sum of the scores for various evaluation criteria as indicator for a high, medium or low risk (Table 3.1). An advantage of the use of scores is that species can be ranked, but it is also associated with arbitrary cut-off thresholds.

Although several protocols apply risk scores, the base for scoring often remains qualitative. Only the UK and Australian protocol explicitly use quantitative elements in the risk assessment procedure. Another important scoring characteristic is the aggregation method (i.e. how are results of various types of impact categories weighted and consolidated into a final indicator for unacceptable risks?). Only the German-Austrian protocol and the Swiss classification key fully apply the 'one out, all out' principle, stating an adverse impact in one category is already indicating a high risk. The Belgian protocol only applies this principle within impact categories, but does not in regard to the final risk outcome. For example, when there are low scores for predation and genetic effects but a high score for transmission of diseases, the overall component for adverse impacts on native species will have a high score.
Listing species (e.g., application of Black and Watch Lists) often results in well defined risk categories, giving a description of invasiveness, (un)certainty and implications for management. The UK Risk Assessment Scheme scores low for this criterion, given that there are no clear definitions of the terms 'high',' medium' and 'low' in the context of summarising risk.
Finally, examples of additional output of a risk assessment are national invasion status (Belgium), additional information on economic and human health impacts (Germany/Austria), social barriers for management (Ireland), climate matching maps (Australia/New Zealand) and extra modules on risk pathways and receptors, management, economic impact and uncertainties (UK).

Table 3.4 Comparison of scoring methods of risk assessment protocols.

Scoring methods	**BE**	**DE/AT**	**UK**	**IE**	**CH**	**AU/NZ**	**US/CA/MX**
Preliminary screening	-	-	++	++	-	-	+
Robustness method							
Likelihood risk	±	±	++	++	±	+	++
Magnitude risk	+	+	+	+	+	++	+
Testing of protocol	±	±	++	+	+	++	±
Use of previous methods	-	±	++	+	±	-	++
Representation values	+	+	+	++	+	±	++
Quantitative elements	-	-	+	-	-	+	-
Weighting	-	-	±	±	-	±	+
Aggregation method ('1 out, all out')	±	++	±	-	++	±	±
Comparability							
Comparability end scores	++	++	+	++	++	-	++
Ranking	+	-	-	+	-	+	-
Endscore indicator	++	++	±	+	++	+	+
Additional output	±	+	++	±	-	+	±

-, ±, +, and ++: not, partly, fairly and extensively elaborated, respectively.

3.2.4 Uncertainty

Uncertainties can occur at three levels: method, reviewer and data. Methodological uncertainty refers to uncertainties as a result of limitations of the risk procedure and should be stated clearly in the protocol. Review uncertainty deals with human errors and subjectivity as a result of the reviewing process. This criterion checks whether this is mentioned in the protocol as well. Data uncertainty or knowledge gaps are another source of uncertainty. Whether uncertainty is also incorporated in the final result is analysed by the fourth criteria.

Table 3.5 shows the first two criteria do not receive attention in all protocols. However, they all more or less clearly state how to deal with uncertainty in data or as a result of knowledge gaps. Uncertainty handling ranges from an indication of uncertainty to an obligation to list and prioritize additional research to reduce uncertainties. Lack of knowledge should not be interpreted as absence of adverse impacts. Therefore, according to five protocols uncertainty also needs to be

incorporated in the results (e.g., final score) of the risk assessment of an exotic species. The UK and trinational Northern American protocols only require an overall indication of uncertainty.

Table 3.5 Comparison of uncertainty handling in risk assessment protocols.

Dealing with uncertainties	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Method	±	+	++	±	-	+	±
Reviewer(s)	+	+	±	-	-	±	+
Knowledge gaps	+	++	++	±	±	±	+
Result	+	++	±	+	++	+	±

-, ±, +, and ++: not, partly, fairly and extensively elaborated, respectively.

3.2.5 Policy compliance

TIE asked to evaluate whether the protocols include relevant criteria to assess risks of exotic species for achievement of goals of national/regional nature policy or nature conservation within a legislative context of the European Union, such as the Birds Directive (Council Directive 79/409/EEC), Habitats Directive (Council Directive 92/43/EEC) and Water Framework Directive (Council Directive 2000/60/EC). All protocols apply one or more criteria which relate effects of exotic species to national or regional policy objectives (Table 3.6). In most cases the impact on endangered or protected species and areas must be evaluated, sometimes with a species reference to actual policy. Only the Irish protocol includes explicit evaluation criteria for effects of exotic species on goals or quality objectives of the European Union for protection of nature, such as the Habitat and Bird Directive and the Water Framework Directive. However, specific guidelines for assessing and valuing these type of effects are not given in the protocol. A further analysis of endpoints related to nature conservation legislation of the European Union is presented in paragraph 3.3.

Table 3.6 Comparison of policy compliance of risk assessment protocols.

Policy compliance	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
European Water Framework Directive	-	-	-	++	-	-	-
European Habitat and Bird Directive	+	-	-	++	-	-	-
National and regional policy	±	+	+	++	±	++	±

-, ±, +, and ++: not, partly, fairly and extensively elaborated, respectively.

3.2.6 User friendliness

The risk assessment protocols range from a simple questionnaire to Microsoft Access applications. The latter obviously requires more detailed guidelines for support to the assessor. All protocols give sufficient guidance to be able to use the material. However, problems may occur in interpretation of assessment questions or criteria. The scores for transparency relating to guidelines in table 3.7 are primarily based on ambiguity of assessment criteria and on the instructions for reviewers to indicate a high, medium or low risk score. The Belgian and Australian protocol score high for this criterion because they give a clear description of the magnitude of effects in relation to the scores that can be given. Second, the accessibility of the outcome of risk assessments to external participants or various end-users is mainly focused on the final risk indication. Listing provides the opportunity of publishing a Black List or when ranking is possible, species with the highest risk can be determined. A high score for this attribute indicates the risk outcome lends itself for publication. Finally, also personal user experience has been evaluated after using the protocols to assess two test species included in this study. This criterion refers to actual use of the guidelines, protocols, MS Access applications and models included in the risk assessment.

Table 3.7 Comparison of user friendliness of risk assessment protocols.

User friendliness	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Transparency							
Guidelines	++	±	+	+	+	++	±
Participants	+	+	++	+	±	+	+
Accessibility	+	+	±	++	+	±	±
Personal user experience	+	++	±	+	++	+	±

-, ±, +, and ++: not, partly, fairly and extensively elaborated and not, little, moderate and very user friendly (for personal user experience), respectively.

3.2.7 Assessment time

Assessment time depends on a number of factors: personal knowledge of a species, availability and quality of underlying data and literature, number of questions etc. The indication of time needed to perform a risk assessment is based on (1) official reviews of protocols and personal communication with risk assessors, and (2) application of the protocols for two test species during this study. The first approach gives an estimate of the total time needed to complete a risk assessment including literature search, consultation of experts, answering the questions and, if applicable, a review process. Reviewers were asked to give an estimate of the average time needed to perform a full risk assessment. The use of the protocols to assess two test species (second approach) gives an indication of filling in the questions only, all literature already available.

The UK Risk Assessment Scheme (being the most elaborate protocol) and the Australian model require most time to complete a risk assessment (Table 3.8). Booy et al. (2006) estimates that a UK risk assessment takes on average more than 19.2 h per species. However, depending on expertise of the risk assessor and available data on species the assessment time for a detailed assessment varies between 5 - 40 h. The Australian model takes on average 36 h for the full procedure, including the ordering of materials, filling in and reviewing questions, climate matching, final review, and producing the final report (W. de Milliano, personal communication 29 March 2010). The average time needed to assess a species using the other protocols ranges from 0.5 to 4 h. It should be noted that all assessors thought it difficult to give an average time indication because this greatly depends on data availability. A time indication for the trinational Northern American protocol was not available.

Personal experience with the utilization of protocols for two test species yields similar rankings for the time required to complete the risk assessments within the Dutch context. Filling in all questions for the UK and Australian protocol took much more time (3 - 4 and 2 h, respectively) than for the other protocols (0.25 – 1 h). However, it should be mentioned that for these test cases available literature was already reviewed and summarized in report by others. So, all input data were ready to use.

Table 3.8 Time required for risk assessments of exotic species using various protocols (in hours).

Assessment time	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Based on reviews and communication with assessors	0.5 - 1.0[1]	2.0[2]	19.2 (range 5 - 40)[3]	Stage 1: 0.1 - 1.0 Stage 2: 4.0[4]	4.0 (range 1 - 16)[5]	36.0[6]	-
Personal experience	1.0	0.25 - 0.5	3.0 - 4.0	0.5 (stage 1 only)	0.5	2.0	1.0

1: S. Vanderhoeven, personal communication 12 April 2010; 2: F. Essl, personal communication 25 March 2010; 3: Booy et al. (2006); 4: J. Kelly, personal communication 24 March 2010; 5: E. Weber, personal communication 12 April 2010; 6: W. de Milliano, personal communication 29 March 2010.

3.3 Characterization of effect criteria

The risk of a species becoming invasive is generally determined by the likelihood and magnitude of harmful effects. But what counts as a significant negative effect depends on more or less subjective judgements by risk assessors and/or the application of formal impact valuation criteria. Explicit impact valuation criteria in risk assessment protocols were analysed for the three major impact categories (ecological, economic and human health impacts; Tables 3.9-3.11). Furthermore, criteria related to ecological impact are discussed with respect to European nature policy.

3.3.1 Ecological endpoints and effect criteria

Endpoints for economic and human health effects can be relatively easy captured in monetary or health terms, but determination of ecological effects is somewhat more complicated due to complexity of biotic interactions and species-ecosystem functioning relations. Exact definitions of ecological damage thresholds are often hampered by lack of sufficient and accurate data on ecological effects of exotic species. Table 3.9 lists the ecological endpoints and effect criteria that are explicitly formalized in various risk assessments protocols. As a result of the complex nature of ecological effects a distinction is made between: (1) effects on native species, (2) effects on ecosystem processes, (3) effects on habitat, and (4) effect characteristics. All protocols include one or more endpoints relating to a reduction of native species populations or biodiversity. Only the Belgian en UK protocols explicitly address the reversibility and scale of effects on reduction of native species populations. Ecosystem effects are also widely recognized, with the exception of the Australian protocol, but the attention paid to ecosystem processes differs greatly. A more equal distribution can be seen in relation to habitat effects. Habitat quality loss is the most important endpoint here. Finally, a variety of effect characteristics can be identified when determining ecological effects. Only the risk classifications of the German-Austrian and Swiss protocol explicitly refer to the certainty of effects.

Common features, returning in all but one protocol, are interactions between species and species traits. The majority of the protocols determine ecological impacts (partly) by specifically addressing interactions such as predation or competition between species (Table 3.10). The Swiss classification key was designed for plants and subsequently has limited endpoints on species interactions.

3.3.2 Effect criteria related to European Birds and Habitats directives

Special attention was paid to effects on EU protected species and nature areas. As already stated in paragraph 3.2.5 the framework for nature conservation legislation within the European Union is formed by the Birds Directive and the Habitats Directive, which were explicitly included in the risk assessment by Ireland only. This framework contains obligations for the Member States concerning both species protection and area protection. More in the background, the conventions of Bern, Bonn and Ramsar play a role in nature conservation policy. In the European Union, the Habitats and the Birds directive are considered to cover these conventions (De Nooij et al., 2008). European legislation has to be implemented and elaborated in national law. Species protection has been implemented into Dutch law by means of the Flora and Fauna Act; area protection in the Dutch Nature Protection Act 1998. An important goal of the nature conservation legislation is maintaining a “favourable conservation status”.
The conservation status of a protected species will be taken as “unfavourable” when:

- Population dynamics data on the species concerned indicate that it is not maintaining itself on a long-term basis as a viable component of its natural habitats, and

- The natural range of the species is being reduced or is likely to be reduced for the foreseeable future, and
- There is, and will probably continue to be, an insufficiently large habitat to maintain its populations on a long-term basis.

The conservation status of a natural habitat will be taken as “unfavourable” when:

- Its natural range and areas it covers within that range are unstable or decreasing, and
- The specific structure and functions which are necessary for its long-term maintenance do not exist and are not likely to continue to exist for the foreseeable future, and
- The conservation status of its typical species is unfavourable.

Table 3.9 Ecological endpoints and effect criteria mentioned in risk assessment protocols.

	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Effects on native species							
Displacement or extinction native species	x	x	x	x	x	x	
Reduction of (local) native species richness	x		x	x		x	x
Reduction or elimination threatened species			x	x	x	x	x
Reduction or elimination key stone species			x				x
Effects on nationally protected species				x	x	x	
Effects on EU protected species				x			
Reversible or irreversible effects	x		x				
Local or widespread effects	x		x				
Effects on ecosystem processes							
Ecosystem stability (not specified)			x	x			x
Change in abiotic conditions	x	x	x		x		x
Disruption of food webs	x	x	x				
Modifications of natural successions	x	x	x				
Vegetation dynamics		x	x				
Effects on habitat							
Habitat quantity loss				x			x
Habitat quality loss				x	x	x	x
Sensitivity of habitat	x		x			x	
Value of habitat	x	x		x			
Effects on nationally protected habitat		x	x	x	x		
Effects on EU protected habitat	x			x			
Effect characteristics							
Suspected or evident effects		x			x		
Positive effects							x
Geographical distribution effects			x			x	
Effects of future control actions			x	x			x

Table 3.10 Species interactions and traits mentioned in risk assessment protocols.

	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Predation/herbivory	x	x		x		x	
Competition	x	x		x		x	
Transmission of diseases	x	x				x	
Genetic effects	x	x	x			x	
Mutualist or host-parasite relations		x					
Natural control or enemies			x				
Facilitation other native species			x	x			
Monopolization of resources		x			x		

Even though the criteria for “unfavourable conservation status” return partially in many protocols, this is to assess general ecological effects and does not aim for EU policy compliance.
If effects might occur, then the possibility of significant effects must be assessed. This assessment must be related to the conservation and management objectives concerning the special areas of conservation. Potential cumulative impacts must also be evaluated.
Member States shall take appropriate steps to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated. This may also hold for the introduction of invasive species. So, assessment criteria in a Dutch protocol for risks of exotic species regarding the achievement of goals of the European Union Birds Directive and the Habitats Directive can be derived from definitions of the above-mentioned terms “favourable conservation status” and “significant effects”. Recently, guiding principles for making significant ecological effects operational in impact assessments were developed by a Dutch committee (Steunpunt Natura-2000 2009). This report states qualification of significant changes in size and quality of populations and/or habitat depends on e.g. precision of measured effects, resilience (of the population or area) and the reference situation.

3.3.3 Effect criteria related to European Water Framework directive

The Water Framework Directive (Directive 2000/60/EC) is the most important legal instrument of the European Commission to achieve protection of water bodies within the European Union. This directive sets that a good ecological quality status must be achieved for all waters by 2015 and that sustainable water use is ensured throughout the European Union. Invasive species may pose negative as well as positive effects on ecological quality status (i.e. on hydro-morphological, physicochemical and biological quality elements) of water bodies. Therefore, the risk assessment of exotic species should also receive special attention within the context of ecological status assessments required by the EU Water Framework Directive (Arbačiauskas et al. 2008). Prevention of further invasions is critically important. Methods for identifying the risk of spread and invasion to previously unaffected waters need to be identified for river basin characterisations. In this way responsible authorities can appropriately target rapid responses in the so-called programmes of measures (Kabula and Stuifzand 2009).
Unfortunately, all evaluated protocols didn’t yet include explicit assessment criteria for effects of exotic species on the ecological quality status of water bodies. However, several risk assessment tools (e.g. biopollution indices) are recently developed to account for effects of exotic species on various quality elements of water bodies (e.g., Arbačiauskas et al. 2008, Kabula and Stuifzand 2009, Panov et al. 2009). These tools can also be adapted and implemented in a Dutch risk assessment protocol for exotic species.

3.3.4 Economic effect criteria

Assessment of economic impacts is performed at different levels. The UK and trinational Northern American protocols give an in-depth analysis of possible economic effects, while the other protocols only give some examples of economical damage or leave the economic impacts entirely open for interpretation by assessors (Table 3.11). Economical sectors often mentioned in protocols are agricultural damage, damage to buildings or infrastructure and profit loss. Three out of five protocols (which assess economic impacts) express damage in monetary terms.

Table 3.11 Economic endpoints and effect criteria mentioned in risk assessment protocols.

	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Economic effects	n.a.	n.a.					
Significant economic losses (not specified)			x	x			
Agricultural damage			x		x	x	x
Damage to buildings or infrastructure					x	x	
Economic importance of hosts							x
Lost ecological services			x				x
Losses due to reduction in profits, consumer demands or export markets			x			x	x
Direct control and management costs			x				x
Research and monitoring costs			x				
Effect characteristics							
Monetary terms			x			x	x
Positive economic effects				x			x

n.a.: not applicable.

3.3.5 Effect criteria for human health

Human health criteria are included in five protocols. In the majority human health effects are judged using only one question or criterion. They relate mostly to harm due toxicity or risks due to parasites or pathogens, but are often not well defined. Only the Australian protocol gives an adequate explanation of type and magnitude of human health effects (Table 3.12). The perspective on human health effects differs as well. The UK scheme combines human health effects and social or other harm in one criterion. But the Australian protocol relates human health effects to (public) safety and the trinational Northern American and Irish protocol capture risks due to human parasites or pathogens in environmental or ecological effects.

Table 3.12 Human health endpoints and effect criteria mentioned in risk assessment protocols.

	BE	DE/AT	UK	IE	CH	AU/NZ	US/CA/MX
Human health effects	n.a.	n.a.	n.s.				
Poisenous or toxicity				x	x	x	
Risk due to parasites or pathogens				x		x	x
Allergenic pollen					x		
Aggressive behaviour (injuries)						x	
Nuisance (e.g., noise)						x	
Other human health effects (not specified)				x			x
Effect characteristics							
Fatality						x	
Number of people exposed						x	

n.a.: not applicable; n.s.: not specified.

Overall, it can be stated that risk assessment protocols focus almost exclusively on negative impacts, excluding any beneficial consequences resulting from introduction. Furthermore, there is little explanation or quantification as to what actually qualifies a significant (harmful) effect. The ecological endpoints or effect criteria remarkably differ between protocols. A clear strategy on determination of ecological impacts is often lacking. Only a limited number of human health criteria are present in most protocols and they are judged from different perspectives. Finally, economic impacts are often related to social, safety, human health and ecological effects and therefore do not represent economic effects alone.

3.4 Strength and weakness analysis

3.4.1 Belgium - ISEIA

Strengths

- It is a generic protocol that can be applied to all taxonomic groups.
- The criteria for the four risk elements (i.e., dispersion potential, colonization of high conservation value habitats, adverse impact on native species and alteration of ecosystem functions) and the associated high, medium and low risk categories are well defined and do not leave much room for discussion. This reduces the subjectivity when assessing the risks of exotic species. But subjectivity is not ruled out when discussing reversible or irreversible damage of exotic species.
- Lists give a distinction between the level of invasion in Belgium (i.e., absent, isolated populations, restricted range or widespread) in relation to management level.

W*eaknesses*

- This protocol only assesses ecological impacts.
- It heavily relies on documented invasion histories in previously invaded areas. A species cannot be properly assessed if a history on invasion elsewhere is not available. This approach may overlook new invaders. The likelihood of introduction is based entirely on invasion history data and there is no assessment of pathways or vectors relating to introduction of non-native species or life-history traits.
- A significant impact on either native species or ecosystems is not decisive for the final judgment of the species. In other words, this will not result in an automatic assignment to the Black List. The risk is determined using the sum of the scores from the four risk elements, using a cut-off threshold to determine low, medium or high risk.

3.4.2 Germany and Austria - GABLIS

Strengths

- The use of a ‘one out, all out’ principle when looking at negative effects on the different impact categories and directly translating this to the Black List status of an exotic species ensures a precautionary approach.
- Uncertainty concerning risks to biodiversity is incorporated in the final risk outcome. There is a Grey List for species which negative impacts are based on evidence based assumptions or distinct indications.
- Future conditions as a result of climate change are included in the assessment. This is important because some exotic species may not show invasive characteristics now but this may change with temperature rise, changes in precipitation patterns or alteration of invasibility by reconstruction or management of receiving habitats.
- The division in different sub-lists take into account available management options and give a clear idea whether management of the species is feasible.

Weaknesses

- GABLIS does not explicitly incorporate economic or health effects in the classification key. The protocol only demands a description of significant negative or positive economic effects and negative effects on human health. Effects on safety are not mentioned at all.
- Some of the biological-ecological criteria can be interpreted very broadly (i.e., reproductive capacity, spread capacity and monopolization of resources). Lack of univocal criteria may cause discussion among experts but also demands detailed data and a high level of expertise when executing the risk assessment.

3.4.3 United Kingdom - Risk Assessment Scheme

Strengths

- Method is based on internationally used and tested risk assessments (EPPO, WRA) and adapted for freshwater fish, marine fish and invertebrates, freshwater invertebrates and amphibians.
- Preliminary assessment gives the opportunity to eliminate species from consideration by quickly screening them for invasibility and impact potential. But this procedure is too summarily elaborated to qualify as a stand alone risk assessment.
- Additional modules for pathway and receptor risk assessment (taking a different perspective than species) and management, to provide a structured analysis of strategies that could be taken.
- The scheme includes all risk assessment components and all impact categories.

Weaknesses

- Impact on biodiversity and ecosystem functioning is determined using a minimal number of criteria to assess environmental impact.
- Criteria concerning the same phenomena are scattered throughout the entire risk assessment. This may make it difficult for reviewers to gain ‘the big picture’ (Booy et al. 2006).
- Module 1 with the embedded spreadsheets overlaps with questions in the main scheme (Booy et al. 2006).
- The quantitative, automated risk calculation is not transparent and there are no clear definitions of the terms ‘high',' medium’ and ‘low’ in the context of summarising risk.

3.4.4 Ireland - Invasive Species Ireland Risk Assessment

Strengths

- Yield an overall assessment of ecological, economical and human health effects
- The preliminary assessment allows for a rapid analysis of a large number of species in a short time period.
- The risk assessment checks interference with national and European policy explicitly.

Weaknesses

- Ambiguous phrasing of assessment questions (e.g., Can a species become widely established? How significant are impacts in terms of change of native species?)
- Arbitrary cut-off point for deciding high risk and medium risk species. Medium risk may still include species with invasion potential, but these are not subject of further assessment.
- The scoring system is weighted and does not provide a truly objective risk classification as it prioritizes species with major ecological impacts, a relatively restricted distribution and for which effective control and containment measures are available. For example, one of the criteria deals with possible societal barriers for management options.

3.4.5 Switzerland - Classification key for Neophytes

Strengths

- Simple but functional risk assessment which analyses all impact categories.
- Final risk outcome takes into account distinction between suspected damage and evident impacts.

- The use of a ‘one out, all out’ principle when looking at negative effects on the different impact categories and directly translating this to the Black List status of a species ensures a precautionary approach.

Weaknesses

- The scheme is only applicable to plants and needs to be adjusted in case of application for other taxonomic groups.
- The introduction phase (e.g., pathways and vectors) of exotic species is not included in the scheme.
- If an exotic species distribution is restricted to urbanized areas, only economic impacts are considered and ecological impacts are not assessed. In a Dutch context this may result in judging a species as non-invasive, even if native species are threatened.

3.4.6 Australia and New Zealand - Risk Assessment Models

Strengths

- Risk assessment includes all impact categories.
- The report is elaborated in much detail and includes argumentations based on scientific literature for the use of criteria in order to achieve objectivity in the risk assessment.
- Use of different risk assessment methods for imported (IRA), vertebrate (Bomford) and plant species (WRA).

Weaknesses

- Use of species specific criteria will not allow easy adaptation of the protocol to non-vertebrate species.
- Arbitrary cut-off threshold to determine between low, moderate, high or extreme intermediate risk scores (establishment risk, pest risk and escape risk).

3.4.7 US, Canada and Mexico - Trinational Risk Assessment Guidelines

Strengths

- Trinational attuning of the protocol.
- It includes all risk assessment components and all impact categories.
- Organizational strength: the information can be organized under the seven elements. This will make communication and peer reviewing easier.

Weaknesses

- The guidelines are developed for aquatic species only.
- Methods used to collect data on the seven elements are not predetermined (though a number of useful tools and models are recommended).
- High, medium and low ratings of the elements are not explained and depend entirely on judgment of experts who execute the risk assessment.
- The final estimate of the Organisms or Pathway Risk Potential only provides a summary of the entire risk assessment and some guidance to for decision-making. But it does not give a direct indication of adverse impacts.

3.5 Testing and evaluation of outcomes risk assessment protocols

Two different approaches for testing of the risk assessment protocols and analysing their outcome were applied: (1) comparison and analyses of available results of various risk

assessment protocols, and (2) risk analyses for a selected group of exotic species using various protocols in the Dutch context.

3.5.1 Comparison and analyses of national risk assessment outcomes

If a species had already been subject of risk assessments in a number of countries, the consistency of the risk outcome of various protocols could be analysed. A literature review of risk classifications of various risk assessment protocols for evaluation of exotic plants, fish, birds and a mammal in a national context yields for 20 out of 29 species (64%) similar risk classifications (Table 3.13). Risk classification remarkably varied for 36% of the species. Differences in classifications may be related to different assessment criteria in risk protocols as well as variability in national context (i.e., invasibility and invasiveness) and in use of literature.

Table 3.13 Comparison of available risk classifications for plants, fish, birds and a mammal in various countries, where the risk assessment protocols in force have been applied in their national context.

	BE[1]	DE[2]	AT[2]	UK	IE[5]	CH[6]	AU
Plants							
Ailanthus altissima	Black list	Black management list	Black management list	n.r.	Medium risk	Black list	n.a.
Ambrosia artemisiifolia	Not invasive	Grey operation list	Grey operation list	n.r.	Medium risk	Black list	n.a.
Azolla filiculoides	Watch list	n.r.	n.r.	High risk[3]	High risk	n.r.	n.a.
Buddleja davidii	Watch list	Grey operation list	Grey operation list	n.r.	Low risk	Black list	n.a.
Cornus sericea	Black list	White list	White list	n.r.	Low risk	Watch list	n.a.
Crassula helmsii	Black list	Grey observation list	Grey observation list	High risk[3]	High risk	n.r.	n.a.
Elodea canadensis	Black list	Black management list	Black management list	n.r.	Medium risk	Black list	n.a.
Elodea nuttallii	Black list	Black management list	Black management list	n.r.	High risk	Black list	n.a.
Fallopia japonica	Black list	Black management list	Black management list	High risk[3]	High risk	Black list	n.a.
Heracleum mantegazzianum	Black list	Black management list	Black management list	n.r.	High risk	Black list	n.a.
Hydrocotyle ranunculoides	Black list	Black action list	Black warning list	High risk[3]	High risk	n.r.	n.a.
Impatiens glandulifera	Black list	Grey operation list	Grey operation list	n.r.	High risk	Black list	n.a.
Ludwigia grandiflora	Black list	n.r.	n.r.	High risk[3]	High risk	Black list	n.a.
Lupinus polyphyllus	Watch list	Black management list	Black management list	n.r.	Medium risk	Watch list	n.a.
Prunus laurocerasus	Watch list	Grey observation list	Grey observation list	n.r.	Medium risk	Black list	n.a.
Prunus serotina	Black list	Black management list	Black action list	n.r.	n.r.	Black list	n.a.
Fish							
Ameiurus nebulosus	Watch list	Black management list	Grey operation list	High risk[4]	Medium risk	n.a.	n.a.
Gambusia holbrooki	n.r.	Grey observation list	Grey observation list	High risk[4]	Medium risk	n.a.	n.a.
Lepomis gibbosus	Watch list	Grey operation list	Grey operation list	High risk[4]	n.r.	n.a.	n.a.
Micropterus salmoides	n.r.	White list	White list	Medium risk[4 *]	Medium risk	n.a.	n.a.
Neogobius melanostomus	Alert list	Black management list	Black management list	High risk[4]	Medium risk	n.a.	n.a.
Pseudorasbora parva	Black list	Grey operation list	Grey operation list	High risk[3]	High risk	n.a.	n.a.
Perccottus glenii	Alert list	Black warning list	Black warning list	High risk[4]	n.r.	n.a.	n.a.
Salvelinus fontinalis	n.r.	Grey operation list	Black management list	Medium risk[4 *]	Medium risk		
Umbra pygmaea	Not invasive	White list	White list	High risk[4]	n.r.	n.a.	n.a.
Mammals							
Dama dama	Watch list	n.r.	n.r.	n.r.	Low risk	n.a.	Extreme[7]
Birds							
Branta canadensis	Black list	n.r.	n.r.	Medium risk	Medium risk	n.a.	Extreme[7]
Psittacula krameri	Watch list	n.r.	n.r.	Medium risk	Medium risk	n.a.	Extreme[7]

n.a.: not applicable; n.r.: not reviewed; *: previous assessment with FISK classified this species as high risk. 1: Harmonia Database (2010), 2: Essl et al. (2010), 3: NNSS (2010), 4: Copp et al. (2009), 5: Invasive Species Ireland (2007), 6: CPS/SKEW (2008) and 7: VPC (2007).

3.5.2 Crossing borders

Verreycken et al. (2009) recently assessed the potential invasiveness of the present and expected non-native fishes in Flanders (Belgium) using the Freshwater Fish Invasiveness Scoring Kit (FISK; Copp et al. 2005, 2009) developed in the UK. The FISK tool is an adaptation of the WRA (Pheloung et al. 1999) and is included as a module of the UK Risk Assessment Scheme (Baker et al. 2005, 2008). It uses 49 questions in eight categories: (1) domestication, (2) climate and distribution, (3) invasive elsewhere, (4) undesirable traits, (5) feeding guild, (6) reproduction, (7) dispersal mechanisms, and (8) persistence attributes. Moreover, it takes into account the confidence (certainty/uncertainty) ranking of the assessors. The FISK score and classification system is presented in the legends to figure 3.1.

When using FISK, mean UK scores were consistently higher (i.e., higher risk to invasiveness) than the Belgian ones (Figure 3.1; Verreycken et al. 2009). For species with little published information, scores between assessors can differ substantially. However, many species received similar scores from both assessors in their respective region, with differences in scores between assessors exceeding 10 units in 18 out of 67 species (27 %) in the UK and 2 out of 21 (9.5 %) in Flanders only (Verreycken et al. 2009).

Similar to Verreycken et al. (2009), FISK was also applied by Mastitsky et al. (2010) to assess the invasion potential of introduced fished in Belarus. Their comparison of Belarus and UK scores showed a similar percentage of species were considered to pose a high risk or medium risk but for six species drastic differences were disclosed. For these species the Belarus scores were much lower, dismissing a high risk classification (Figure 3.1; Mastitsky et al. 2010). An explanation given by the authors is the use of dual independent assessments for each species by Copp et al. (2009), while in the Belarus study species were assessed by only one assessor. Figure 3.1 shows a higher correlation between the scores for Flanders and Belarus (only one species differs in risk classification). Higher correlation between Flanders and Belarus versus Flanders/Belarus and UK may be related to variability in the bio-geographical and ecological setting of continental water systems versus that on islands.

The German-Austrian Black List Information System, as an international protocol, allows for comparison of GABLIS scores for Germany and Austria. A comparison of assessments of exotic vascular plants and freshwater fish in a German and Austrian context shows that for plants and fish, respectively 17% and 10% of the species were classified differently. These dissimilarities reflected both differences in current distributions and different habitat availability in the two countries (Essl et al. 2010).

Finally, a comparison of the Australian risk outcome of the risk assessment model for exotic vertebrates (Bomford 2003, 2008) for the house crow and the application of this model in a Dutch context (Slaterus et al. 2009) could be made. These two risk assessments indicate differences related to climate matching as well. The Dutch version consistently scored lower for climate matching which subsequently resulted in a lower end score. But both risk assessments rated the house crow as an extreme threat.

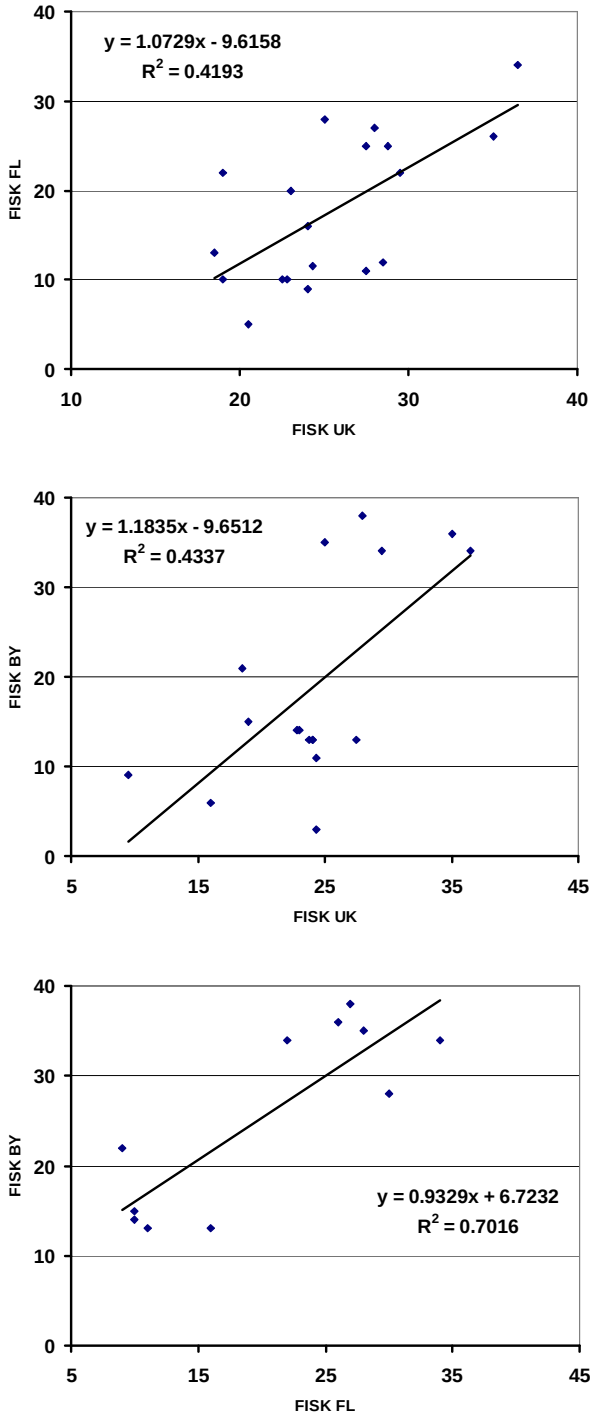

Figure 3.1 The outcome of risk assessments of exotic fish species with FISK performed by the assessors from UK, Belgium (FL, Flanders) and Belarus (BY). Scores can range from −11 to 54 and they classify non-native species into low, medium, and high risk categories (High risk: ≥ 19, 1 ≤ Medium risk < 19, Low risk: < 1). Data: Copp et al. (2009), Mastitsky et al. (2010) and Verreycken et al. (2009).

3.5.3 Different risk assessment protocols applied in national context

Verreycken et al. (2009) also compared scores resulting from two risk assessment tools in a Belgian context: FISK (Copp et al. 2005) and the Belgian ISEIA (Branquart 2007). The ISEIA protocol assesses the potential of non-native species for spreading and colonising natural habitats as well as the adverse impacts on native species and ecosystems and assigns invasive alien species to an alert, watch or black list (Section 2.1.1; Branquart 2007). High impact species present in Belgium are on the black list while those with a moderate or unknown impact are included in the watch list. The alert list consists of high impact species present in neighbouring countries but not yet recorded in Belgium.

Of the nine fish species assessed by the Belgian ISEIA protocol, four are placed on the black list; these species have correspondingly high scores in FISK. However, eight out of four score ≥19 and are considered high risk invasive species when FISK is applied in a Belgian context (Verreycken et al. 2009). Despite the fact that FISK and ISEIA use different scoring systems, Verreycken et al. (2009) concluded that they manage to categorize the fishes more or less in the same 'invasiveness classes'. Both protocols are regarded to represent useful and viable tools to aid decision- and policymakers in assessing and classifying freshwater fishes according to their potential invasiveness.

Inversely, the ISEIA protocol has recently been applied as a screening tool in order to identify potential invasive non-native animal species in England (Parrott et al. 2009). In this study the UK scores from the ISEIA protocol were compared with the FISK scores from Copp et al. (2009) and the Freshwater Invertebrate Invasiveness Scoring Kit (FI-ISK) scores from Tricarico et al. (2010). The comparison with Copp et al. (2009) is the same method used by Verreycken et al. (2009) and described in de previous paragraph, only in a UK context. Of the calibrated FISK scores for twelve fish species eight fall within the high risk category. Using the adapted ISEIA scheme, all but four species are classed as low risk (Table 3.14). Parrot et al. (2009) explain the underestimation of risk using the ISEIA scheme by stating that the number of questions (i.e., the sample size of interrogation about the species) in the ISEIA protocol is insufficient.
Unlike the previous comparison, the ISEIA assessments were in general agreement with those of FI-ISK (Tricarico et al. 2010). One of five species was classed lower by ISEIA than FI-ISK (Table 3.15).

Table 3.14 Comparison of invasiveness risk scores for fresh and brackish water fishes using the ISEIA and the FISK schemes (from Parrott et al. 2009), whereby H is high risk, M is medium risk, L is low risk, with lower and middle ranks of FISK referring to a score's relative position (lower or intermediate 1/3) within that risk rank.

Latin name	Common name	ISEIA scheme	FISK mean score	FISK rank
Neogobius melanostomus	Round goby	H	29.5	middle H
Ameiurus melas	Black bullhead	M	28.8	middle H
Aristichthys nobilis	Bighead carp	L	24.3	lower H
Ctenopharyngodon idella	Grass carp	L	24.0	lower H
Catostomus commersoni	White sucker	L	23.0	lower H
Hypophthalmichthys molitrix	Silver carp	L	22.8	lower H
Gambusia holbrooki	Eastern mosquitofish	M	21.0	lower H
Pimephales promelas	Fathead minnow	L	19.0	lower H
Proterorhinus marmoratus	Tubenose goby	H	18.5	upper M
Cyprinella lutrensis	Red shiner	L	18.0	upper M
Acipenser ruthenus	Sterlet	L	16.0	upper M
Misgurnus fossilis	Weatherfish	L	12.5	middle M

Table 3.15 Comparison of invasiveness risk scores for freshwater invertebrates using the ISEIA and the FI-ISK schemes (from Tricarico et al. 2010), whereby H is high risk, M is medium risk, L is low risk, with lower and middle ranks of FISK referring to a score's relative position (lower or intermediate 1/3) within that risk rank.

Latin name	Common name	ISEIA scheme	FISK mean score	FISK rank
Procambarus clarkii	Red swamp crayfish	M	39	upper H
Orchonectes limosus	Spiny cheeked crayfish	H	30	upper H
Astacus leptodactylus	Narrow-clawed crayfish	M	15	upper M
Procambarus sp.	Marbled crayfish	M	15	upper M
Astacus astacus	Noble crayfish	L	0	L

Verreycken et al. (2010) recently performed a detailed review of the potential impact of the eastern mudminnow (*Umbra pygmaea*) in Flemish lotic waters using the abovementioned protocols. FISK, when applied by Belgian assessors, placed this species in the 'medium risk' category of becoming invasive (score of 14), while the eastern mudminnow was not allocated to one of the lists of the ISEIA protocol and thus considered non-invasive. However, Copp et al. (2009) allocated this fish species to the high risk category (score of 24.0) of potentially invasive species. According to Verreycken et al. (2010), the paucity of (peer-reviewed) publications on the introduced range and the ecological impact of the eastern mudminnow may explain the differences in outcome of the assessors (UK versus Belgium) and of both assessment tools as the results are probably mainly based on expert judgment. The few publications that deal with the ecological impact (and distribution) of eastern mudminnow are mainly about extreme habitats (e.g., acidified moorland pools) where this fish can occur in high densities and often is the only fish species present. Answers from the Belgian assessors in the risk assessment were based on their knowledge of the distribution and impact of *U. pygmaea* in lotic waters in Flanders with low densities of this fish. In these rivers it seems appropriate that *U. pygmaea* is categorized as a species with "low to medium risk" of becoming invasive. According to the German-Austrian Black List Information System risk assessment of *U. pygmaea* in the German and Austrian context the species gains a low risk (white list) classification (Table 4.1).

The above-mentioned comparisons clearly show that the outcomes of protocols are rather consistent for the majority of tested species. However, paragraph 3.4.1 showed the assessments of a substantial number of species (up to 36%) yield inconsistent or different risk classifications. In a national context the use of different risk assessment procedures may yield differences as well. Scores from the Freshwater Invasiveness Scoring Kit (developed in the UK) tend to be higher than scores from the Invasive Species Environmental Impact Assessment (developed in Belgium) when assessing the same species for the same country. The use of the same protocol in different climatic regions also gives different risk classifications. Important factors affecting the risk classifications are differences in data availability, current distributions, habitat availability, environmental matching, expertise and number of assessors, and scoring systems. The results underline the absolute necessity of risk assessments of exotic species within a regional or national context.

3.5.4 Risk assessments for selected species in Dutch context

The available protocols were also used to assess risks of two exotic species in the Netherlands. These risk assessments were performed for a terrestrial and aquatic species, the house crow (*Corvus splendens*) and round goby (*Neogobius melanostomus*) respectively. The species were selected based on data availability and invasion status. Data of existing risk evaluation reports recently produced by Dutch research institutes (the so-called Pest Risk Analyses; in Dutch: Plaag Risico Analyses) for these species can be used as they already compiled available

literature. A report from the foundation on Reptile, Amphibian and Fish Conservation Netherlands, consultancy Natuurbalans-Limens Divergens and the Radboud University Nijmegen is available for ten Ponto-Caspian gobies, including the round goby (Spikmans et al. 2010) and the Dutch Centre for Field Ornithology has conducted a risk assessment for the house crow (Slaterus et al. 2009). The latter already included a risk assessment based on the Australian risk assessment model of Bomford. Therefore, the Australian procedure was not repeated for the house crow. For some countries risk assessments for these species were already available and these assessments only needed to be adapted to the Dutch situation. Although the Swiss classification key is designed for plants, the format has proved to be applicable to the two test species as well. The results of the performed risk assessments for the house crow and round goby are summarized in appendices 2 and 3, respectively.

Table 3.16 Comparison of risk classifications of the house crow (*Corvus splendens*) and round goby (*Neogobius melanostomus*) using different protocols in a Dutch context.

Protocol	***Corvus splendens***	***Neogobius melanostomus***
ISEIA	Not invasive or watch list	Black list
GABLIS	Black action list	Black management list
UK Scheme	High risk	High risk
Ireland Risk Assessment	Medium risk	Medium risk
Swiss Classification Key	Black list	Black list
AU Risk Assessment Model	Extreme threat	Extreme threat
Trinational Guidelines	n.a.	High risk

n.a.: not applicable.

The house crow risk classifications are not consistent and range from not invasive to medium risk or high (extreme) risk (Table 3.16). This species is a nuisance for other animals, but also for humans because it lives in (sub)urban environments. This is a reason why the species could score lower in protocols that limit risk assessments to ecological effects. Another explanation for the low(er) risk score of the ISEIA protocol, is that the risk outcome is determined by four elements (the potential for spread and establishment and adverse impacts on native species and ecosystems) which are summed to a final risk score. GABLIS on the other hand applies the ‘one out, all out’ principle where only one (ecological) impact is enough to place a species on the Black list.

The round goby is classified as a high risk (or assigned to a Black list) by all protocols, with the exception of Ireland. In stage 1 of the Irish risk assessment for established species a total of 25 points can be gathered and a high risk indication is only given if the total score is greater than 19. The round goby scored 18 points, mainly because of lack of information on (or unknown) human health and economic effects.

The application of various protocols for two test species reveals that small changes in the assessment (slightly different judgments of available data) can lead to different risk outcomes. This is in particular the case when the risk assessment protocol uses cut-off thresholds to determine the final risk classification (i.e., ISEIA and Ireland Risk Assessment).

4 Towards a risk assessment protocol for the Netherlands

With respect to content of risk assessments of exotic species none of the eight protocols meets all evaluation criteria or could be considered ideal within the Dutch context. However, the judgment of a protocol should always depend on the objectives for conducting risk assessments, such as performance of a rapid initial, site-specific or generic assessment. Nonetheless, based on our evaluation criteria, characterization of effect criteria and strength-weakness analysis of the risk assessment protocols a number of recommendations for the development of a generic, comprehensive and performable protocol can be made.

Firstly, the possibility for generic use of one of the available protocols is limited by the completeness of the risk assessment procedure. Our comparison shows that the UK Risk Assessment Scheme is the only protocol that complies with all criteria for scope and completeness. However, it must also be said that none of the other protocols score low for these criteria. Only the Belgian and German-Austrian protocol have limitations with regard to impact categories, but can be relatively easily extended with questions and criteria for the impact categories economy and human health. Moreover, full adaptation of the Australian protocol will not be possible due to species specific assessment elements. So, implementation of this protocol in the Dutch context will require several modifications.

Secondly, uncertainty plays an important role in risk assessment of exotic species and should be well accounted for in a protocol. Uncertainty is mentioned in each protocol. However, not all protocols explicitly include uncertainty in a final score or oblige clauses to the outcome of the risk assessment. A lack of knowledge may never be interpreted as absence of adverse impacts (Davis 2009). The impacts of exotic species are very much context dependent. Ecological consequences of invasions of the same species differ from site to site owing to abiotic and biotic differences among sites. Moreover, if currently it is highly certain that negative impacts are not observed, this outcome does not necessarily mean that negative impact may not occur in the future under environmental change. Uncertainty may also be caused by a lag phase between spread and establishment which may delay or reduce harmful effects. If a species has only recently established the full extent of their impacts may not yet be known. However, harmful effects can also lessen when equilibrium has been reached. Uncertainty in the final score is accounted for most when a distinction is made between evident and uncertain or unknown effects, as incorporated in the German-Austrian and Swiss approach where species are assigned to a monitoring or watch list in case of lacking scientific evidence. Whether prevention or mitigation of these monitoring species is practised (following the precautionary principle) is a policy based decision.

Thirdly, an important feature in calculating risk is the aggregation of the impact categories to a final risk score. Two approaches can be distinguished: (1) summing up the scores for the different impact categories (and invasion potential) usually combined with a cut-off threshold, and (2) applying a ‘one out, all out’ principle, where an adverse impact in one category is sufficient to add a high risk label. Considering the main objective of risk assessment as prevention of adverse impacts, the latter approach seems most appropriate. The ‘one out, all out’ principle is applied in the German-Austrian and Swiss protocol. The listing approach used in these two protocols does not allow ranking of high risk species to prioritize mitigation and eradication measures for controlling invasive species. Quantification of or giving scores to ecological, economical and human health effects will give more insight in the magnitude of impacts. A generic impact scoring system has been developed by Nentwig et al. (2009;

Appendix 4) and includes definitions of impact levels for ecological and economic (including human health and safety) effects. Application of such a scoring system will offer more guidance to policymakers than presentation of a Black List only. However, scoring can also neglect local effects and impacts from Grey List species.

Fourthly, invasion history is considered an important predictor in risk assessment of exotic species and is an important data supply in all protocols. Especially the Belgian protocol relies heavily on documented invasion histories. For the assessment of relatively new or less well-known invaders this approach may proof to be inappropriate, because it always underestimates the potential risks of these species.

Fifthly, since no scientific evidence exists that one specific impact category (e.g., species competition or damage to agriculture) is more important than others weighting of one or more (sub)categories would be adding a social dimension to the risk assessment (as is the case in the UK, Ireland, Australia and US/Canada/Mexico; Table 3.4). In order to provide a more 'objective' risk assessment, the procedure should give equal weight to each impact category and should not display policy related preferences. Social interference also occurs when the feasibility of management options is included in the risk assessment. Risk assessment classifications are often linked with management options, but only the UK scheme and Irish protocol included management options and societal barriers in the risk assessment procedure. For example, it was included in the Irish protocol because this was in line with the overall objective of the Invasive Species Ireland Project. The other protocols sometimes assess feasibility of management options to make a distinction between species with or without possibilities for management (e.g., the different sub-lists in GABLIS). However, they do not use this criterion to determine the risk posed by exotic species. In practice, the ideal way to make risk based decisions is to carry out an objective risk assessment which then grounds policy decisions.

Finally, the risk assessment procedure itself is vital. Clear descriptions of assessment questions and judgment categories make sure the risk assessment procedure is consistent and similarly judges potential risks of exotic species. All protocols include a number of ambiguous criteria or assessment questions, which should be adjusted. In addition, it will be required to provide more clarity and guidance for assessors concerning the application of these criteria, i.e. what is considered as a (significant) detrimental effect.

The UK Risk Assessment Scheme is most elaborated and therefore requires much time and effort to complete. Considering the fact that other protocols have similar content and yield more or less similar risk indications, we recommend the use of a more simplistic approach for generic risk assessment of exotic species, as applied by most European countries. The labour-intensiveness of the UK scheme has also been acknowledged by the national government who has recently used the ISEIA protocol to conduct a quick screening of potential invasive species before conducting a detailed assessment (Parrot et al. 2009).

The differences in risk classifications for various countries and climatic regions underline the absolute necessity of quick as well as detailed screenings of exotic species within the Dutch context. Therefore, we recommend developing a multiple stage risk assessment protocol for the Netherlands. For a generic and quick screening of introduced and potential exotic species (first step) a straightforward European risk assessment protocol can be adopted and fine tuned for the Dutch context. Adopting such a protocol will also ensure coherence with EU policy strategies and legislation and will contribute to European harmonization of risk assessment protocols. The 'one out, all out', listing approach used in Germany/Austria and Switzerland provides a practical and meaningful risk approach. However, use of these protocols in the Netherlands would require

additional impacts categories (i.e., economy, human health and safety; GABLIS) or adaptations to assess all taxa and modification of the site or context specific risk criteria (Swiss classification key). In the second step a more detailed assessment (of pathways, impacts or uncertainties) can be conducted to obtain more specific data on a species. The UK Risk Assessment Scheme has useful attributes in this respect.

5 Conclusions and recommendations

5.1 Conclusions

1. A recognized United Nations or European Union format for assessing risks resulting from exotic species introductions is not yet available. However, a variety of regional, national and international risk assessment protocols are being used or are currently being developed. The short history of risk assessment of exotic species shows that initial protocols are often revised or adapted in order to optimize their performance and to improve predictions.

2. The eight protocols included in this study have different characteristics and content. The scope of the protocols ranges from assessing ecological effects only (i.e., Belgium, Germany/Austria and Norway) to inclusion of ecological, economical, human health as well as social effects (i.e., UK, Australia and US/Canada/Mexico). Impact is regarded a major factor when determining risk posed by exotic species but more extensive protocols (i.e., UK and Ireland) also require numerous data on pathways and factors related to establishment. The latter will not only be required for assessing potential effects of exotic species, but it is also vital to derive preventive measures and other feasible management options. The number and detail of assessment criteria also differ widely between the risk assessment protocols. Based on the evaluation criteria the UK Risk Assessment Scheme is the most comprehensive scheme, but consequently it also is the most data and labour-intensive one.

3. This study appoints the ‘one out, all out’, listing method (applied in the German-Austrian and Swiss protocol) as a robust risk assessment method for a rapid and generic screening. This conclusion is mainly based on the relatively limited data requirements, high user friendliness and a high consistency of their risk classification in comparison with more extensive approaches. According to GABLIS an ecological threat is present when: (1) (a) population(s) of native species are threatened, (2) the colonisation of further similar localities is likely to lead to endangerment or extinction of native species in large parts of its distribution range or (3) ecosystem processes or properties are significantly altered, with a distinction between suspected and evident impacts. The Swiss classification key addresses similar ecological effects on plants and in addition effects on human health and the economy are assessed. Both protocols apply a precautionary approach with the use of a ‘one out, all out’ principle, meaning one (evident) detrimental impact is decisive en will result in assignment of an exotic species to a Black list. The Black list status of a species implies that negative effects for these species are confirmed and (preventive) management actions have to be undertaken. A detailed assessment of these species will give more information on pathways, spread, impact categories etc. needed to develop effective management and control strategies.

4. From our evaluation of ecological impact criteria we conclude that most protocols hardly give any explanation or quantification as to what actually qualifies a significant (harmful) effect. In order to give reviewers more grip on what is considered a significant effect and to guarantee consistency between risk assessments a clear description of the assessment approach, the effect criteria and corresponding risk indications should be given. Useful guidelines for determining significant effects are available from Steunpunt Natura-2000 (2009).

5. The comparison of risk classifications of various protocols applied to exotic species in different countries shows the necessity for regional risk assessment. Different risk classifications may occur due to differences in species-climate or species-environment

match in various countries or biogeographical regions, in data availability, and experience and number of risk assessors.

5.2 Recommendations for development and implementation of a Dutch protocol

1. Based on the present evaluation we recommend developing a multiple stage assessment approach for risk classification of exotic species in the Netherlands. The first step may comprise the rapid generic screening of risks posing by potentially arriving and established exotic species. This screening may result in a classification of (potentially) harmful exotic species on a Black list (high risk species). In case of medium (or acceptable) risk classification, lack of data or considerable uncertainty in the assessment, a species can be classified on a so-called alert list (synonyms watching, monitoring or grey list). The current Dutch evaluation reports (so-called 'Plaag Risico Analyses' as performed by TIE) extensively review available literature on potential spread and impacts of various taxonomic groups or individual species and can deliver input data that are required for the first step screening. The second step may comprise a more detailed risk assessment that also includes a thorough evaluation of available management options to eradicate invasive exotic species or to mitigate their negative impacts.

2. For a quick and generic screening of introduced and potential exotic species the approach of the German-Austrian protocol (GABLIS) is recommended with the following adaptations:
   - Include economic, human health and safety effects in (or before) the first step of the classification key. These can be derived from the additional information gathered by GABLIS on economic and human health effects (Essl et al. 2010; Supplementary online material D). Another useful set of definitions for economic impacts (including health and safety) is developed by Nentwig et al. (2009; Appendix 4).
   - Give a clear definition of the additional and biological-ecological criteria which are used to distinguish between the Grey observation list and White list (Essl et al. 2010; Supplementary online material C). An enhanced verbal description will make the process more transparent and reproducible.

   Adopting the Swiss protocol would require adjustments to suite all taxonomic groups. This requires changes in the description of possible effects (from plant-oriented to taxon- generic descriptions). The framework itself does not require any changes to enable generic taxonomic use but it needs to be adapted to the Dutch context with respect to the valuation of ecological effects (i.e., the possibility of harmful effects in human-mediated areas).

3. In the second step of a multiple stage risk assessment, high risk exotic species should be subjected to a more detailed assessment in which for example high risk pathways, specific impacts and uncertainties can be studied. This approach can be different for each species depending on their risk assessment specifics. From this study we conclude that the UK Risk Assessment Scheme, founded on previous risk assessment tools (i.e., WRA and EPPO) and thoroughly reviewed, also has useful attributes for a detailed assessment (excluding the preliminary assessment). For example, the use of species-specific invasive attributes spreadsheets (e.g., FISK, FI-ISK and others) which will probably increase reliability of prediction and the scheme also allows for detailed uncertainty analyses.

4. Both the German-Austrian and Swiss protocol use a listing approach which may have a disadvantage in relation to decision-making. Prioritization of mitigation and eradication measures is needed to be able to divide limited resources available for controlling invasive species. Listing provides merely a partition between high, medium and low risk species and does not allow ranking of species. The risk classification of the UK Risk Assessment Scheme does not allow ranking of species either. Giving scores to impact categories or even just the count of the number of impact categories relevant for species classified as high risk could indicate high priority species. The definitions of impact levels from Nentwig et al. (2009; Appendix 4) may provide a framework for scoring ecological and economic impacts (including effects on human health and safety).

5. More general recommendations concerning the content and use of a risk assessment protocol for exotic species are:
   - To make use of a separate Climate list which comprises species which have harmful or unknown effects but are currently physiologically constrained from establishing due to unfavourably temperate conditions and require climate warming before establishment could potentially occur. GABLIS already incorporated a biological-ecological criterion on facilitation by climate change (Essl et al. 2010; Supplementary online material C). This criterion could be singled out to form a separate Climate list.
   - To incorporate possible negative and positive effects of exotic species on goals of EU nature and water policy and legislation (such as required by the EU directives), as this is lacking in the majority of the protocols (except the Irish protocol).
   - To ensure an independent review process to validate outcomes of risk assessments and to evaluate implications of major uncertainties for cost-effective management of exotic species.

5.3 Recommendations for further research

1. Prevention of invasions is often much less costly than post-entry control. In addition, bioinvasions are in many cases irreversible and can only be prevented in an early stage. Risk assessment protocols are a useful tool in predicting invasiveness but uncertainty and limitations cannot be ruled out completely. Further research should therefore be committed to reliable predictors for invasiveness which can be used in risk assessments.

2. Criteria for impact assessment also necessitates further research as impact definitions are often vaguely formulated. Moreover, economic impacts are often addressed separately but are in practice related to environmental impacts (e.g., decline in fish stock), safety (e.g., muskrat) and human health (public health).

3. Although most protocols use qualitative methods to determine risks of invasive species, the scientific literature show growing interest in scientific development and application of taxon specific quantitative risk approaches and models (for example from Wu et al. 2010). These quantitative tools may provide more sophisticated impact analyses and can further reduce uncertainties with respect to predicting likelihood of establishment, climate matching and spatial distribution of effects of exotic invaders, as required for detailed species-specific risk assessments. Because these tools have not yet become an integral part of risk assessment protocols, future research may also be focussed on the review of novel quantitative risk assessment tools for exotic species and opportunities for integration of these tools in the Dutch protocol.

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Appendix 1 Evaluation criteria

Table 1.1 Criteria for completeness of risk assessment protocols.

General	
Taxonomic scope	Is the risk assessment taxonomically universal (generic)?
	Is the risk assessment suitable for all ecosystem types?
Life cycle	Are (all) life stages of species taken into account in the risk assessment?

Risk assessment components	**Number of risk assessment components in risk assessment**
Introduction	Does the risk assessment include the introduction phase?
	If yes:
	To what extent is the introduction of non-native species explored?
	Does the risk assessment have separate assessments for established and potential invasive species?
	Are pathways and vectors explicitly mentioned and explored?
Establishment	Does the risk assessment include the establishment phase?
	If yes:
	To what extent is the establishment of non-native species explored?
	Is propagule pressure properly quantified?
	Is establishment success elsewhere considered (invasion history)?
	Is climate and/or habitat matching considered?
Spread	Does the risk assessment include spread?
	If yes:
	To what extent is the spread of non-native species explored?
	Is the rate of spread considered?
	Is the ability to spread considered?
Impact	Does the risk assessment include impacts?
	If yes:
	To what extent are the impacts of non-native species explored?
	Does the impact assessment include indirect effects (e.g. facilitating other introductions)?
	Does the impact assessment also include potential impacts due to changing environmental conditions?
	Are positive impacts as well as negative impacts taken into account?
Management	Does the risk assessment include the management phase?
	If yes:
	To what extent is management of non-native species explored?
	Are regulations (e.g. ballast water) taken into account?
	Are successful management options evaluated?
	Are management difficulties considered?
	Are management options considered for all invasion stages?

Table 1.1 continued.

Impact categories	Number of impact categories considered in risk assessment
Biodiversity	Does the risk assessment include negative effects on biodiversity?
	If yes:
	To what extent are negative effects on biodiversity assessed?
	Are interactions with native species (competition, predation, hybridization, parasitism and infection) considered?
	Are both loss of species (populations) and loss of habitat (size) considered?
Ecosystem functioning	Does the risk assessment include impacts on ecosystem functioning?
	If yes:
	To what extent are negative effects on ecosystem functioning assessed?
	Are significant changes in ecosystem functions considered?
	Are habitat alterations considered?
Economy	Does the risk assessment include negative impacts on economy?
	If yes:
	To what extent are negative effects on economy assessed?
	Are costs for eradication and control considered?
	Are negative impacts on ecosystem services considered?
Human health	Does the risk assessment include impacts on human health?
	If yes:
	To what extent are negative effects on human health assessed?
	Are viral pathogens considered?
	Are (infectious) disease vectors considered?
	Are plant characteristics which enhance allergic reactions considered?
Safety	Does the risk assessment include impacts on safety?
	If yes:
	To what extent are negative effects on safety assessed?
	Are impacts on infrastructure considered?

Table 1.2 Criteria for data requirements.

Data requirements	
Degree of scientific base	Does the RA include reference to the credibility of spread and sighting via an institutionalized knowledge framework?
	Is it clearly stated how original sources of (supporting) data should be adequately documented?
	Is there an explicit demand for high quality references (peer reviewed)?
Spatial data included	Is site specific data (e.g. abiotic conditions) included in the assessment?
Temporal data included	Is global (climate) change included in the assessment?
Level of expertise	Is the level of expertise needed to conduct the risk assessment minimal, medium or high?
Feasibility	(How) Is dealt with knowledge gaps in risk assessments?
	Do the assessment questions allow for inclusion of outcomes from already executed risk assessments?

Table 1.3 Criteria for scoring methods.

Scoring methods	
Preliminary screening	Does the risk assessment have a preliminary screening before conducting a detailed assessment?
Robustness method	Is the magnitude of impact and establishment scored in risk assessment?
	Is the likelihood of impact and establishment scored in risk assessment?
	Has the protocol been adequately tested?
	Does the protocol make use of applications of previous (successful) risk assessment protocols?
	Do the assessment questions represent relevant economic, ecological and/or social values?
	Does the procedure include quantitative elements?
Weighting	Does the procedure make (explicit) use of weighting factors?
Aggregation method	Does the procedure apply a one out all out principle when determining the final risk classification?
Comparability end scores	Are end scores for all species comparable?
	Does the risk indicator give a clear statement on the invasive nature of the species?
	Is ranking of invasive species possible after assessment?
Additional output	Does the risk assessment give additional outputs (e.g. level of uncertainty, risk management options or sector specific impact?

Table 1.4 Criteria for dealing with uncertainties.

Uncertainty	
Method	Is uncertainty as a result of methodological features clearly stated and analysed?
Reviewer(s)	Is indicated how is dealt with different opinions from experts?
Knowledge gaps	Is there an obligation to analyse uncertainty as a result of the knowledge gaps?
Result	Is uncertainty incorporated in the final score?

Table 1.5 Criteria for policy compliance.

Policy compliance	
	Are positive as well as negative effects on policy objectives considered and how are these weighted?
European Water Framework Directive	Does the protocol include (implicit) criteria to check compliance with the European Water Framework Directive?
	Does the ecological impact assessment refer to specific criteria for ecological status assessment of various types of surface water bodies (i.e. hydromorphological, physico-chemical or biological quality criteria)?
European Habitat and Bird Directive	Does the protocol include (implicit) criteria to check compliance with the European Habitat and Bird Directives?
	Are significant impacts on the quantity (distribution and surface area) and quality (specific structure and functions) of special areas for conservation (Natura 2000 areas) considered?
	Are significant impacts on the distribution, reproduction, mortality, population size and population viability of protected species considered?
	Are long term, indirect, external or cumulative effects also considered?
National and regional policy	Does the protocol include (implicit) criteria to implicitly check compliance with the national or regional nature policy objectives?
	Does the ecological impact assessment refer to feasibility of specific objectives of national or regional nature conservation policy?

Table 1.6 Criteria for user friendliness.

User friendliness	
Transparency	Is each step in the risk assessment sufficiently documented (traceable) in guidelines?
	Is it clearly stated who the participants in the risk assessment are (e.g. executive and cooperating organisation(s))?
Accessibility	Do the final assessment and score lend themselves for publication on the web?
Personal user experience	Subjective judgment of user friendliness after assessing test species (e.g. guidelines clear?)

Table 1.7 Criteria for assessment time.

Assessment time	
Based on reviews and communication	Can you give an estimate of the average time needed to perform a risk assessment?
Personal experience	What time is needed to complete a risk assessment with all literature available?

Appendix 2 Risk scores for *Corvus splendens*

ISEIA Protocol

Table 2 Sub and final scores ISEIA protocol for *Corvus splendens*.

		Optimistic	Precautionary
Subscores	Dispersion potential	3	3
	Colonisation of high conservation habitats	1	1
	Adverse impact on native species	3	3
	Alteration ecosystem functions	1	2
Final score		**Not invasive**	**Watch list**

Score alteration ecosystem functions:
Optimistic score alteration ecosystem function:
Low risk - no effect on nutrient cycling, no physical alterations and no modification of natural successions or food web sections.
Score: 1

Precautionary score alteration ecosystem functions
Likely effect on food web sections
Score: 2
Final score: 8 (not invasive) or 9 (watch list)

GABLIS
Black action list
Alien species living in the wild is causing a threat for native species according to the state of scientific knowledge. *Corvus splendens* occur only in a few localities and appropriate control or eradication measures are known.

Invasive Species Ireland Risk Assessment
Stage 1 assessment for established species
- Optimistic scenario: Carrier of parasites potentially harmful for human health but no scientific evidence which indicate risk. Total score: 16 – medium risk (no need for a detailed assessment)
- Precautionary scenario: Potentially harmful to human health already indicates risk.
Total score: 17 – medium risk (no need for a detailed assessment)

Swiss Classification Key
Species is showing invasiveness in other countries, but no significant human health risk and lives primarily in human mediated environments. Economic impact determines classification: species has caused considerable economic losses in other countries due to damage to crops etc. which places this species on the Black list (while no economic impact would have dismissed this species as invasive).

Risk Assessments Model for Exotic Invertebrates (included in Slaterus et al 2009)
Establishment risk – high
Pest risk – high
VPC Threat category – extreme threat

UK Risk Assessment Scheme
Based on UK risk assessment of the house crow and adapted to the Dutch situation.
Entry: very likely
Establishment: very likely
Spread: slow spread
Impacts: major
Conclusion of the risk assessment: high risk

Appendix 3 Risk scores for *Neogobius melanostomus*

ISEIA Protocol

Table 3 Sub and final scores ISEIA protocol for *Neogobius melanostomus*.

Subscores	
Dispersion potential	3
Colonisation of high conservation habitats	3
Adverse impact on native species	3
Alteration ecosystem functions	2
Final score	**Black list**

GABLIS

Black management list

Alien species living in the wild is causing a threat for native species according to the state of scientific knowledge. *Neogobius melanostomus* is widely distributed in the Netherlands.

Invasive Species Ireland Risk Assessment

Stage 1 assessment for established species

Total score: 18 – medium risk (no need for a detailed assessment)

Swiss Classification Key

Species is showing invasiveness in other countries, but no significant human health risk. The species does live in natural habitats and has been shown to cause decline in populations of native species. Because the species is still spreading and has more than 5 distinguishable populations, this species is placed on the Black list.

Risk Assessments Model for Exotic Invertebrates

Climate match score: 8 (more than 90% of the stations included in category 6-10)
Overseas range score: 4 (present in North America (NA), Europe (EU) and Asia)
Establishment score: 3 (EU, NA and Asia)
Introduction success score: 4 (success rate > 0.75; Fishbase data from 2006)
Genus risk score: 5 (success rate > 0.60; Fishbase data from 2006; including *Neogobius melanostomus, Neogobius fluviatilis, Neogobius gymnotrachelus and Neogobius kessleri*).
Total score: 24 – extreme threat

UK Risk Assessment Scheme/FISK

FISK score 27 – high risk

UK Risk Assessment Scheme

Entry: very likely
Establishment: very likely
Spread: moderate
Impacts: major
Conclusion of the risk assessment: high risk.

Appendix 4 Definitions of impact levels for alien mammals (Nentwig et al. 2009)

1. Ecological impact

1.1 Herbivory

0 No impact known or detectable.
1 Similar impact as native species, no major damage to plants reported.
2 Similar impact as native species, recorded negative impact on flora, impact only on abundant species.
3 Generalist herbivore, impact through unselective grazing on plants adapted to grazing, limited damages to trees, minor changes in plant communities with impact on endemic species, negative impact on seed dispersal.
4 Grazing and damage to trees by bark stripping and/or antler rubbing, damage to endemic species, recorded vegetation change reversible.
5 Grazing in areas not adapted to large herbivores, e.g. island ecosystems, high damage through bark stripping and/or antler rubbing, threat to endemic and plant species listed as vulnerable, endangered or critically endangered by IUCN, local extinctions or permanent community changes.

1.2 Competition

0 No impact known or detectable.
1 Very low level of competition with at least one native species, exploitation competition.
2 Competition with several native species by exploitation competition, without large impact on affected species or decline of their populations.
3 Competition with several species for food and/or space, interference competition, at least one native species declining.
4 Competition with many native species, several declining in population size, competition for food and/or space, behavioural changes in out-competed species.
5 Competes with species listed as vulnerable, endangered or critically endangered by IUCN, decline of these species, replacement or even extinction of species.

1.3 Predation

0 No impact known or detectable.
1 Predation known but negligible, no decline of native species.
2 Predation on several abundant species, without large impact on affected species or decline of their populations.
3 Decline of one to several native species recognized, no changes in food web structure reported.
4 Decline of many species, indirect impact by mesopredator release, changes in the food web.
5 Preys also on endemic or species listed as vulnerable, endangered or critically endangered by IUCN, local extinction.

1.4 Transmission of diseases to wildlife

0 No impact known or detectable.
1 Host for non-specific parasites, occasional transmission of more or less harmless diseases to one native species. No population decline in native species.

2 Occasional transmission of more or less harmless diseases, several native species affected. No or only minor population decline in native species.
3 Many native species affected, frequent transmission of more or less harmless diseases or harmful diseases transmitted to one native species. Minor population decline in native species.
4 Transmits harmful diseases to several native species or more or less harmless diseases to endemic or species listed as vulnerable, endangered or critically endangered by IUCN. Moderate population decline in native species.
5 Transmits harmful diseases to many species and/or species listed as vulnerable, endangered or critically endangered by IUCN by direct transmission, decline of these species or extinction.

1.5 Impact on fauna: hybridization
0 No impact known or detectable.
1 Hybridization possible in captivity, but only rarely in the wild.
2 Hybridization is more common in the wild, no offspring, but constraints to normal mating.
3 Hybridization is more common, with offspring, but not fertile.
4 Hybridization common with fertile offspring.
5 Risk of extinction of endangered species.

2. Economic impact

2.1 On agriculture
0 No impact known or detectable.
1 Only occasional damage to crops or plantations, damage similar to native species.
2 Damage to crops more common.
3 Damage through feeding and trampling on crops, occasional threat to stored food, damage exceeds impact of the native fauna.
4 High damage in fields or to stored food, bark stripping, gnawing bark in fruit plantations and/or fruit consumption.
5 Complete destruction of fields or plantations, or of stored food by consumption and contamination.

2.2 On animal production
0 No impact known or detectable.
1 Occasional competition with livestock.
2 Competition with livestock, transmission of diseases to livestock in the native area, but not yet reported from the area of introduction.
3 Competition more frequent with several livestock species, transmission of diseases reported, but infection rates low, predation on game animals, or otherwise economically important species.
4 Transmission of economically important diseases or predation on livestock or hybridization with economically important game animals.
5 Transmission of harmful diseases to or hybridization with livestock.

2.3 On forestry
0 No impact known or detectable.
1 Minor impact through herbivory.
2 Impact through herbivory, minor effect on forest growth, impact on seed dispersal.
3 Constrains forest regeneration through browsing on young trees, damage to plantations, gnawing of bark, damage by causing floods.

4 Moderate to strong damage to mature forest through seed consumption, bark stripping or antler rubbing, death of trees by felling or flooding.
5 Very strong damage to mature forest through seed consumption, bark stripping or antler rubbing, death of trees by felling or flooding.

2.4 On infrastructure

0 No impact known or detectable.
1 Biological traits and life-style suggest potential damage to infrastructure, but not yet reported.
2 Occasional damage with minor economic losses, e.g. damage to fences.
3 Damage to fences and/or plantations, gnawing electricity cables etc., causing road accidents.
4 High damage with considerable economic costs, damage through burrowing or nesting in buildings, impact through pollution.
5 Considerable damage to flood defence systems, danger to human safety.

2.5 On human health

0 No impact known or detectable.
1 Host of one or more harmless diseases with the possibility of infecting humans, not yet reported.
2 Host of several harmless diseases, indirect transmission or possibility of direct transmission, but only a small percentage of the human population at risk.
3 Direct infection with one or more harmless diseases, occasionally health thread through bites or other attacks.
4 Direct transmission of several diseases, infection by contaminated food common, host of harmful diseases in the native range, but not yet known from the invaded range. Health thread through bites or other attacks happen more often.
5 Vector of harmful diseases to humans and/or many diseases frequently transmitted. Health thread through bites or other attacks happen frequently.

Appendix 5 List of experts consulted

Dr. E. Branquart, Belgian Biodiversity Platform, Belgium.

Dr. M. Braysher, Institute for Applied Ecology, University of Canberra, Canberra, Australia.

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Appendix 6 List of acronyms

ANSTF: Aquatic Nuisance Species Task Force

CAPRA: Computer Assisted Pest Risk Analysis

CBD: Convention on Biological Diversity

CEC: Commission for Environmental Cooperation

CPS/SKEW: Swiss Commission for Wild Plant Conservation

EPPO: European and Mediterranean Plant Protection Organisation

FISK: Freshwater Fish Invasiveness Scoring Kit

FI-ISK: Freshwater Invertebrate Invasiveness Scoring Kit

GABLIS: German-Austrian Black List Information System

ISEIA: Invasive Species Environmental Impact Assessment

TIE: Invasive Alien Species Team

VPC: Vertebrate Pest Committee

WFD: Water Framework Directive

WRA: Weed Risk Assessment